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THE ROYAL SANITARY INSTITUTE,
90, BUCKINGHAM PALACE ROAD,

THE SEWAGE QUESTION:

COMPRISING

A Series of Reports:

BEING

INVESTIGATIONS INTO THE CONDITION

OF

THE PRINCIPAL SEWAGE FARMS

AND

SEWAGE WORKS OF THE KINGDOM.

FROM DR. LETHEBY'S "NOTES AND CHEMICAL ANALYSES."

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PREFACE.

At the present time when the Sewage Question is commanding a large share of public attention, and is even a matter of commercial speculation, it has been thought that a reprint of the valuable and exhaustive articles on this subject from the pages of the *Medical Press and Circular*, with corrections and additions by Dr. Letheby, from whose notes and analyses they were originally compiled, would not only be of great interest to the public, but would also tend to dissipate the many specious illusions, and to clear away the mass of errors which have congregated about it; for, to speak truly, it has been so tampered with by ignorant pretenders, by vehement enthusiasts, and by designing speculators, that the real facts of the question have been almost lost in the clouds of error. It is hoped, however, that these reports will dissipate the obscurity; and by placing the subject in a proper light will enable local authorities, and others interested in the matter, to perceive the actual truths of the question —so that when called on to apply them practically,

they may be able to avoid the disappointment and legal penalties which have too often followed a false conclusion. Above all it is hoped that the sanguine expectation of commercial profit, derived from exaggerated notions of the agricultural value of sewage will be repressed ; and that local authorities, whose functions it is to provide for the health of the community in their charge, will be persuaded to regard the subject entirely from a sanitary point of view.

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SEWAGE QUESTION.

In a recent Number of the Medical Press and Circular we published the valuable paper read by Dr. Letheby, and discussed before the Metropolitan Association of Medical Officers of Health, "On the Present Prospects of the Sewage Question in Relation to the Public Health," and this important contribution to the knowledge of the most urgent sanitary question of the day has excited public attention, and brought out further discussion in various quarters. Since then, too, another blue book has been published by the Royal Commissioners on the Pollution of Rivers ; and the Health Department of the Social Science Association has arranged that the first special subject for consideration at the Congress next month shall be the best method of disposing of sewage and animal excreta.

For the above and other reasons this has appeared to us a peculiarly favourable time to take up and discuss in detail the great questions relating to sewage—questions which, whether regarded from a hygienic, agricultural, or commercial point of view, cannot be too thoroughly sifted, and which in all their phases can only be grasped by those who have competent medical and chemical knowledge.

We therefore determined to make use of the machinery at our command for the preparation of one of these Special Reports for which the MEDICAL PRESS has long been well known. The duty of our reporters is to collect and lay before our readers in the simplest form the most important facts, so as to furnish a complete digest of the results of the subject already attained, from which we may afterwards draw such inferences as the inquiry may justify.

As the chemical investigations of this matter must of necessity be of the utmost importance to the inquiry, and as Dr. Letheby has spent much time in such investigations, and has become a deservedly high authority on the subject, we requested our chief London editor to apply to his learned colleague for permission to peruse his notes on the places he had visited. This permission was immediately accorded, for the Doctor at once freely placed at his disposal the whole of the notes he had taken on the actual condition of the sewage farms of this country, and of all the works where chemical processes are employed for the purpose of defæcating sewage.. These notes, therefore, will furnish the basis of the Report; for we shall publish them in a condensed form, so as to provide our readers with a reliable account of what has been done at every place where any attempt has been made to cope with the sewage question.

Our staff have also been promised the assistance of other competent observers who have visited these places; and we trust that the facts we have to submit, and the conclusions we may have to deduce, will not only take rank as of permanent value, but will also assist in the solution of a great national problem. The plan of our report is simple: we shall commence with an account of the several sewage farms of the country, and then proceed to describe the various precipitating processes; after which we shall take a comprehensive review of the whole subject.

DISPOSAL OF SEWAGE BY IRRIGATION.

ALDERSHOT SEWAGE FARM.

The farm lies to the north-east of the two camps, and it consists of about 112 acres of land, of which 89 are under cultivation ; of these about 46 acres are laid out for Italian rye grass, and 2 or 3 acres for rhubarb, which, we are informed, nobody will eat a second time, on account of its rank sewage flavour.

The soil consists of very porous sand, with a ferruginous subsoil. The sewage amounts to about 200,000 gallons a day. It comes from the north and south camps, where there are about 10,000 soldiers, with a supply of about 20 gallons a head daily. It is a strong sewage, representing the pure sewage of an adult population with no manufacturing operations. It flows from the camp for a distance of nearly two miles through eighteen-inch earthenware pipes, with an average incline of 25 feet in a mile, but the incline is not regular and the pipes are too large, and the scour is not good. When it arrives at the head of the farm it is discharged from the two pipes into a common open channel, which delivers it to the subsiding tank, where there is a coarse contrivance for straining the sewage by an upward flow through perforated planks, and then it runs over a weir into the channel which conveys it to the carriers from which it flows over the land. The solid mat-

ters which are strained off from the sewage are conveyed to a pit where they are mixed with gas lime and other refuse matters, and are then used for manure ; but the amount of solid matter thus kept back is not large, for in twelve months it only amounted to about 300 tons in its wet state.

At the time of our visit, the farm was in a very offensive condition, for although the great bulk of the sewage was not flowing upon the land at all, but running bodily into the Blackwater stream, yet the remains of previous irrigation were lying about in cakes of partially dried fœcal matter, which would be washed away into the nearest streams and ditches by the first heavy shower of rain. The ground, in fact, was everywhere sodden, and stinking, and the rye grass was dying out, and the usual rank water grass taking its place.

At the lower part of the grounds there is a military or occupation road which bounds the farm, and on the opposite side of the road there are a few cottages and beer houses, the inmates of which complained bitterly of the frequent stenches from the farm, the sewage of which flowed into the neighbouring ditches and ponds, and thus rendered the place a stinking swamp. Most of the sewage at the time of our visit was running from the farm across the road, and either going at once into the Blackwater stream or running upon the meadows behind the houses. At the places where the sewage was running into the Blackwater stream the bed of the river was silted up with the solid matters of sewage, and rendered most foul and offensive. Samples of the sewage (No. 1.) were taken from the head of the farm as it came from the camp, and (No. 2.) after it had been strained, and (Nos. 3, 4, 5, and 6) as it was flowing from the farm to the Blackwater stream from four of the outfalls.

A sample of the Blackwater stream (No. 7) was also taken immediately before the entrance of the foul sewage water from the farm into it ; and the following are the results of the analysis of the several samples :—

Constituents per gall.	No. 1.	No. 2.	. 3.	No. 4.	No. 5.	No. 6.	No. 7.
	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.
Solid matter in solution	53·93	53·73	51·67	52·47	58·20	54·13	18 93
Chloride of Sodium	14·92	15·36	16·98	17·08	24·01	20·64	4·12
Organic matter .	30·01	31·70	27·89	24·21	20 69	22·10	3·56
Ammonia . .	7·54	7·54	6·40	6·40	5·04	5·12	0·18
Ditto Organic .	0·94	0·91	0·56	0·64	0·48	0·48	0·08
Nitrogen as Nitrates, &c. . .	0·00	0·00	0·00	0·00	0 00	0·00	0·26
Oxygen required to oxydise . .	4·38	4·40	4·20	3·81	3·30	3·61	0·35
Matters in suspension .	43·77	35·01	3·84	25·91	6·14	4·80	2·68
Organic matter .	29·75	26·24	2·18	12·28	1·98	3·22	0·69
Mineral ditto .	14·02	8·77	1·66	13·63	4·16	1·58	1·99

These results show that the so-called purification of the sewage by irrigation was merely a pretence, for the soluble constituents of the sewage were but little improved by the process, the organic matter of the effluent water being still

over twenty grains per gallon, and the amounts of suspended matters also considerable. In a sanitary point of view, therefore, the process was highly unsatisfactory, for not only was the sodden sewage ground evolving a most offensive odour, which the inhabitants said was sometimes most sickening, but the effluent water was still a strong sewage, polluting the ditches and watercourse to such a degree as to render them a most serious and dangerous nuisance.

Considering how highly the Royal Pollution Commissioners had spoken of this Aldershot Farm, and of the success of the process,* we were not prepared for the shocking condition of things which we witnessed.

We have no means of ascertaining the commercial facts of the case, but if any sewage farm can ever be made to pay it must be in such a case as this, where both the land and sewage are given to the tenant for a peppercorn rent. We are strongly inclined to think, however, that the commercial results are not as profitable as they are made to appear, for the farm is evidently neglected, and the produce is of the rankest description.

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* "In this case the extreme natural poverty of the soil does not seem to have been a hindrance to the efficiency of the process of cleansing by irrigation. The farm, *well managed,* is covered with a capital plant of vigorous growth, to be fed by the filthy water, which accordingly is greatly purified by the process. * * *

"The Aldershot Farm appears the more satisfactory as an example of *the sewage nuisance abated,* at the same time that its filthy contents are converted into valuable produce, from the circumstance that a previous attempt to deal with it by subsidence and filtration tacitly had been a complete failure."

First Report of the Commissioners appointed in 1868 *to inquire into the best means of preventing the pollution of rivers.*—p. 78.

BANBURY SEWAGE FARM.

THE sewage farm is about one mile east of the town of Banbury. It consists of about 136 acres of a sandy clay soil, not very porous ; and about forty-eight acres are under Italian rye grass, and the rest is pasture.

The population of Banbury is between 11,000 and 12,000, and the sewage amounts to about 300,000 gallons a day. It flows by gravitation from the town to the tanks of the old sewage works, where it settles for a time, the mud and scum being removed from it and mixed with street sweepings and other refuse, and sold in a solid state for manure. The liquid portion is lifted by steam power and conveyed to the head of the sewage farm, which is rather more than a mile off, and about twenty-one feet above the level of the tanks. It then runs by carriers over the ground, and finally into the river Cherwell, which is close to the lower part of the farm.

At the time of our visit, in the month of April last, the ground was sodden with sewage, and the side ditches were full of decomposing sewage, the smell from which was very offensive. There is only one house near the farm, and that is a little beerhouse called the Bowling Green, the landlady of which said that the smell from the farm was sometimes most sickening. We took a sample of the

sewage at the head of the farm, and another from the effluent channel as it ran from the subsoil drain into the culvert which passes under the railway to the river Cherwell, and the following are the results of the analyses :—

Constituents per gallon.	Raw sewage.	Effluent water.
	Grains.	Grains.
Solid matter in solution . .	48·87	39·73
Chloride of sodium . .	8·94	8·46
Organic matter . . .	16·49	12·21
Ammonia	3·81	0·48
Do. organic . .	0·28	0·05
Nitrogen as nitrates, &c. .	0·00	0·63
Oxygen required to oxydise	1·42	0·83
Matters in suspension . .	3·27	0·38
Organic matter . . .	1·86	0·13
Mineral ditto . . .	1·41	9·25

A large portion of sewage was passing from the side ditches of the irrigated ground into the water course which flowed towards the river, and this was much worse than the above, which was from the subsoil drain.

Five thousand pounds have been borrowed to make the ground fit for irrigation, and a rental of £4 10s. an acre is paid for the land. Last year the returns from sale of crops, &c., was £160 less than expenses and interest of money. The farm, therefore, is to that extent a losing affair, and the sanitary results are most unsatisfactory; but the town, as usual, is glad to have a respite of its legal difficulties, under any pretence and if only for a short time; for assuredly the serious question of fouling the river is as far from being settled as it ever was.

WARWICK SEWAGE FARM.

This farm was visited in the month of April last. It s situated about one mile from the town, and consists of about 102 acres of stiff clay land under cultivation with Italian rye grass. The population of Warwick is about 11,000, and the sewage amounts to about 600,000 gallons a day. It runs by gravitation from the town to the subsiding tanks, where the suspended matters are in great part removed from it, and it is then pumped to the head of the farm, which is about fifty feet above the tanks.

The farm was in a sad plight at the time of our visit, for the winter frost had killed the grass upon large portions of the fields, and the sewage was running over the ground in a very offensive state.

Samples of the sewage were taken at the entrance to the farm and at its exit from it; and the following are the results of the analysis of each sample :—

Constituents per gallon.	Raw sewage.	Effluent water.
	Grains.	Grains.
Solid matter in solution. .	47·21	52·63
Chloride of sodium . .	11·04	9·12
Organic matter . . .	12·95	7·42
Ammonia	2·20	0·52
Ditto organic . . .	0·14	0·03
Nitrogen as nitrates, &c. .	—	0·10
Oxygen required to oxydise	0 86	0·48
Matters in suspension . .	24·67	0·26
Organic matter . . .	11·87	0·13
Mineral ditto . . .	12·89	0·13

As the land is composed of stiff clay, the purification of the sewage is dependant entirely on the action of atmospheric oxygen, and the absorptive power of the growing plants. In summer time, however, when the clay cracks, the sewage soaks into the ground, and reaches the sub-soil water without undergoing the least purification, and in winter time it flows bodily over the soil, and discharges itself into the out-fall ditch in the same condition as when it reaches the farm.

The farm has been in hand about two years. It originally cost about £12,000 for plant and for laying it out, and a rent is paid of £3 an acre, and £1 for taxes, making a total of £4 per annum per acre; and last year the produce just paid the working expenses of the farm, without interest of money or cost of superintendence.

RUGBY SEWAGE FARM.

THE population of Rugby is about 9,000, and the sewage amounts to from 220,000 to 250,000 gallons a day. It flows by gravitation partly to the old works, which distribute the sewage to the low level fields, and partly to the new works, at a higher level. At both places, however, the operations are the same—the sewage being strained through perforated boards, with holes about one and quarter inch diameter, and six inches apart; and then it flows by open carriers over the ground.

At the low level works the sewage (amounting to about one-third of the whole supply) is distributed over about sixteen acres of land, of the nature of a loose gravelly clay, upon a subsoil of clay which rests upon stone.

The high level sewage (amounting to two-thirds of the supply) is distributed upon forty-nine acres of land, of the same nature of soil, and which is entirely laid out with Italian rye grass.

The farm is about a mile west of Rugby, and at the time of our visit it was, in places, quite saturated with sewage, and had an offensive odour, and it was not until it had flowed successively over three or four portions of land that it was sufficiently purified to be admissible into a running stream; and even then the lower out-fall channel which runs parallel with the river was in a very foul condition.

We took samples of sewage at its entrance upon the farm, and at its exit at two places into the river Avon, and the following are the results of the analysis of them :—

Constituents per gallon.	Raw sewage.	Effluent water.	Effluent water.
	Grains.	Grains.	Grains.
Solid matter in solution -	36·67	37·87	38·60
Chloride of sodium -	8·41	7·44	8·39
Organic matter - -	12·36	9·69	11·51
Ammonia - - -	4·43	1·28	1·28
Ditto organic - -	0·16	0·08	0·08
Nitrogen as nitrates, &c.	0·00	0·21	0·13
Oxygen required to oxydise - -	0·92	0·42	0·63
Matter in suspension -	1·28	0·32	1·15
Organic matter - -	0·64	0·13	0·58
Mineral ditto - -	0·64	0·19	0·57

On another occasion, when samples were taken, they yielded the following results :—

Constituents per gallon.	Raw sewage.	Effluent water.
	Grains.	Grains.
Solid matter in solution . .	43·30	36·11
Chloride of sodium . .	—	—
Organic matter . . .	6·10	2·49
Ammonia	3·841	0·480
Do. organic . .	0·120	0·080
Nitrogen as nitrates, &c. .	0·220	0·231
Oxygen required to oxydise	0·953	0·302
Matters in suspension . .	9·52	0·00
Organic matter . . .	4·48	0·00
Mineral ditto . . .	5·34	0·00

The farm, which has been worked for many years by enthusiastic irrigators, has been in several hands, who have invariably abandoned it at last, on account of the unprofitable results, and for the last two years it has been worked as a matter of necessity by the local Board of Health, who have spent about £5,000 upon it, and who pay a rental of £4 an acre for the land, which, with rates and taxes, amounts to £4 10s. an acre.

Last year the receipts were from £70 to £80 over the working expenses ; but this does not include the interest of the money borrowed, or the cost of superintendence. In Mr. Walker's time, the local board rented the sewage to that gentleman for £50 a year, but although he had a lease of it for twenty-one years, dating from the year 1853, yet he declined to continue it to the end of his of his term, on account of the yearly loss to him ; and so also it was found to be unprofitable by Mr. Campbell, who likewise abandoned it, and hence the local authority have been obliged to take it in hand on their own account, and much against their wishes, for sanitary purposes.

WORTHING SEWAGE FARM.

The sewage of Worthing is leased by the local board of the place to a company called the Worthing Land Improvement Society, who have contracted to take the sewage for twenty-one years on the following terms—namely, for the first seven years for nothing, for the second seven years at a rental of £10 per annum, and for the third seven years at an estimated value derived from the previous fourteen years' experience. The local board is under an obligation to deliver it, on the above terms, upon the land of the society, and the society have wisely agreed to take no more of the sewage than they like, and only when they like.

The sewage farm consists of about ninety-six acres, of which about eighty-three are under irrigation, half being pasture land and the rest Italian rye grass.

The soil is a very porous loam to the depth of from two to six feet, under which there is gravel lying upon chalk. The soil is, therefore, admirably suited for irrigation purposes.

The town of Worthing has a resident population of about 7,500, and it is so well drained and sewered that the flow of sewage during the day time is at the rate of 55,000 gallons per hour.

For the sake of economising the steam-engine power of the water-works, the whole of the sewage of the town is brought by gravitation to two sewage tanks or wells about thirty feet deep, adjoining the chalk wells from which the water-supply of the town is obtained, and it is lifted from these tanks by the water-works' engine to a height of about nine feet above the ground, and delivered by means of a wooden trough to the irrigation grounds belonging to the Land Improvement Society. In this manner about four-fifths of the day sewage, but none of the night, is distributed upon the land, which, as usual, is sodden and offensive. The composition of the sewage and of the effluent water was as follows :—

Constituents per gallon.	Raw sewage.	Effluent water
	Grains.	Grains.
Total solid matter in solution .	30·33	40·67
Chloride of sodium . .	—	—
Organic matter . . .	2·37	1·25
Ammonia	0·235	0·089
Ditto organic . . .	0·075	0·021
Nitrogen as nitrates, &c. .	0·338	0·340
Oxygen required to oxydise	0·323	0·123
Matters in suspension . .	4·38	0·00
Organic matter . . .	0·87	0·00
Mineral ditto . . .	3·51	0·00

It is evident, from these results, that the sewage of Worthing is largely diluted with subsoil water, and that it is of little value for agricultural purposes ; but, diluted as it is, the Land Society do not take one-third of it, the rest being allowed to flow from the tanks into the Teville stream, which carries it into the sea to the eastward of the town. Time will show how far the undertaking of the company is a sanitary success, for the condition of the

Teville is still very unsatisfactory, and the proximity of the sewage well to the water-supply well is, at least, suspicious.

As to the commercial profits of the undertaking, we could obtain but little information, but they ought to be considerable, seeing that the sewage is put upon the land and given to the company by the local authority, and that the company can take it only when they choose. This is a condition of things that few would object to agriculturally, for if the supply were merely water, a farmer would be only too glad to enter into an arrangement with a local authority for such supply when he required it. It is, however quite another affair to be obliged to take it at all times and in all seasons, whether required or not, and to deliver the effluent water in a pure condition.

THE SEWAGE MEADOWS AT CARLISLE.

The population of Carlisle is about 31,000, and the sewage of the town amounts to about 800,000 or 900,000 gallons per day. It flows towards the river Eden by two outfalls, one of which still runs into the bed of the river, and the other is leased to Mr. McDougall, at a nominal rent, for fourteen or twenty-one years. The sewage from this outfall amounts to about 500,000 gallons a day, and it flows by gravitation to a well at Willow-holme, which is at the head of the irrigation fields. It is there treated with a solution of carbolate of lime in the proportion of two gallons of crude carbolic acid and 18 lbs. of lime to the day's sewage. The carbolate of lime runs into the sewage in a graduated stream, and the mixture is lifted by a Gwynn's pump, that is worked by a steam engine of eight-horse power, and discharged into a trough upon a rather high bank which skirts the farm for about half a mile. From this trough it is distributed upon the land wherever it is required, by moveable iron gutters, about six feet long and a foot wide, placed end to end. There are about forty of these discharges, and they are changed every twelve or fourteen hours, so that the whole of the

land, amounting to about 120 acres, is thus irrigated at least three times a year. The land is entirely grazing land for sheep and cattle, and is let to a butcher of the town at a rental of £8 an acre.

The soil is composed to a considerable depth of disintegrated red sandstone, and is so porous that the sewage quickly disappears from the surface, and is lost in the subsoil water, there being no actual outfall into the river. To obtain, therefore, a sample of the effluent water, we were obliged to dig a hole in the ground and collect the subsoil water. This, together with a sample of the original sewage, was submitted to analysis, with the following results :—

Constituents per gallon.	Raw sewage.	Effluent water.
	Grains.	Grains.
Solid matter in solution . .	30·17	17·67
Chloride of sodium . .	—	—
Organic matter . . .	6·25	2·15
Ammonia	1·920	0·192
Ditto organic . . .	0·120	0·020
Nitrogen as nitrates, &c. .	0·036	0·103
Oxygen required to oxydise	0·780	0·278
Matters in suspension . .	3·62	Not ascertainable.
Organic matter . . .	2·17	
Mineral ditto . . .	1·45	

In this case the sewage was much below the average strength, and was evidently diluted to a large extent with subsoil water before it reached the works; and the effluent water obtained from the hole in the ground was also much diluted with river water, so that the purifying effect of the land upon it was not clearly discoverable.

One fact, however, of great importance was manifest, namely, that the addition of carbolate of lime to the

sewage arrested its decomposition, and prevented it from being offensive when distributed over the ground, without injuring vegetation.

The commercial profits of this undertaking are not very clear, although we were informed by Mr. McDougall that he had spent about £1,800 upon the plant, &c., of the farm, and that he paid all the cost of distributing the sewage upon the ground, as well as the rent of it (£4 an acre); and that in return he obtained £8 an acre for the land. This was the condition of things in 1867, and we are inclined to think that the sewage is used only when it is required, there being no compulsion to use it always, and to deliver the effluent water in a pure condition. Under these circumstances, as we have already said, there should be no doubt of profit, as the question is entirely apart from sanitary obligations.

CROYDON SEWAGE FARM.

The population of Croydon is about 50,000, and the water supply, which is constant, amounts to about forty-nine gallons a head. The sewage varies in quantity, according to the state of the weather, from 3,000,000 to 5,000,000 gallons a day, and it flows in two directions—namely, to the Beddington farm, which receives the largest proportion of it, and to the Norwood farm.

The *Beddington Farm* is a little to the west of the town, and about a mile from the Town Hall. It consists of 382 acres of very porous soil upon a deep bed of gravel, and of these about 270 acres are under irrigation by means of open carriers. The sewage, which amounts to about 2,000,000 gallons a day in dry weather, and to more than double that quantity in wet weather, flows by gravitation to the straining tanks, where a portion of the solid matters are detained and removed from it. It then runs through open irrigation channels upon the land, about thirty or forty acres being used at a time for three days, and the crop is chiefly Rye grass, with a little permanent grass, and water cresses are cultivated in the effluent streams. Mangold wurzel and other crops have been tried, but without sufficient success to encourage a repetition of them, except for purely experimental purposes.

The land is at all times in a sodden and offensive condition, and according to the evidence of Mr. Creasy, the surgeon of the neighbouring orphan asylum, who practises largely in the district, and of Mr. Smee, the eminent surgeon and fellow of the Royal Society, who has a garden in the locality, the smell is sometimes quite sickening. Mr. Creasy, indeed, states that typhoid fever is nearly always present in the houses about the farm, and that all diseases assume a typhoid character, so that Medical men speak of the patient as having a sewage tongue.

Samples of sewage were taken from the farm, as well as samples of outfall water, and the following are the results of the analysis of them :—

Constituents per gallon.	Raw sewage.	Effluent water.
	Grains.	Grains.
Solid matter in solution . .	27·67	27·17
Chloride of sodium . .	—	—
Organic matter . . .	2·20	0·75
Ammonia	2·000	0·120
Do. organic . .	0·240	0·015
Nitrogen as nitrates, &c. .	0·000	0·349
Oxygen required to oxydise	0·432	0·242
Matters in suspension . .	10·16	0·00
Organic matter . . .	4·12	0·00
Mineral ditto . . .	6·04	0·00

From which it is evident that the sewage is very weak from dilution with subsoil water, and that it is sufficiently purified by the soil to be admissible into a running stream. It would seem, however, from the Report of the Rivers' Pollution Commission (p. 88), that during frost the purification of the sewage is much impaired, especially when the sewage is strong. It must also be stated that the whole of the subsoil water of the locality is so tainted as

to be unfit for drinking purposes, and that every well is polluted ; in fact, according to the analytical inquiries of Dr. Frankland, as stated by Dr. Carpenter, the chalk well in Croydon, from which the water supply for the town is obtained, is charged to a large extent with nitrates, and the other oxydised products of sewage.

The *Norwood Sewage Farm*, which receives the other outfall sewage, is situated at South Norwood, a little beyond the parish boundary of Croydon. It consists of thirty-seven acres of stiff clay land, to which about twenty-four acres of additional land of the same character are about to be added. The sewage amounts to about 300,000 gallons a day, and it is furnished by about 5,000 persons. As in the last case, the sewage flows to the farm by gravitation, and after being strained, to separate the coarser solid matters, it is run upon the ground by open carriers, and, where it is likely to be very offensive, by partly covered drain-pipes. The ground is chiefly laid out with Italian rye grass, although a few mangolds and potatoes have been grown by way of experiment, but the success of the experiment does not appear to be encouraging.

As might be expected, the ground, which is an impervious clay, is always in a very noisome condition, and the sewage is not sufficiently well purified, except during the time of active vegetation, to be admissible into a running stream ; in fact, there are great complaints of the stench of the sewage, and of the effluvium from the irrigated ground, by those who reside in the neighbourhood ; and the Rivers' Pollution Commissioners say in their report (p. 86), that during frost the purification of the sewage is not at all satisfactory, for they remark that, on two occasions, when "the frost was by no means severe, yet the organic nitrogen rose from 0·098 to 0·419 per 100,000 parts of effluent water, showing that the removal of offensive nitrogenous organic matter was partially arrested, and indicating that during a severe winter the purification of sewage upon a non-absorptive clay soil may be seriously interfered with," and on some other occasions, when the

effluent water was "exceptionally impure," they think it arose from unpurified sewage gaining access to the outfall drains through cracks in the soil. These, in fact, are just the difficulties which stand in the way of the purification of sewage, whenever it is distributed upon impervious clay soils, and soils that are liable to crack in dry weather.

The samples of raw sewage and of effluent water which were taken and analysed had the following composition :—

Constituents per gallon.	Raw sewage.	Effluent water.
	Grains.	Grains.
Solid matter in solution . .	41·00	58·19
Chloride of sodium . .	—	—
Organic matter . . .	3·49	4·00
Ammonia	2·000	0·320
Do. organic . .	0·320	0·040
Nitrogen as nitrates, &c. .	0·556	0·601
Oxygen required to oxydise .	0·916	0·824
Matters in suspension . .	11·01	1·98
Organic matter . . .	6·03	0·18
Mineral ditto . . .	4·98	0·80

In this case, as in the faulty cases referred to by the Rivers' Pollution Commissieners, the effluent water was in a very unsatisfactory condition, and so it has been on other occasions when we have examined it.

As regards the commercial success of these farms, it would seem that until recently the farm at Beddington has been let to Mr. Marriage for £5 an acre, the local Board paying a rent of £4 an acre, so that the return to the Board has been £1 an acre for the sewage, and for the cost of supplying it, and for the outlay which they have encountered in preparing the ground—the profit, therefore, considering all things, cannot be much, if there be any ; and on attempting to raise the rent of the farm, the tenant has declined to continue in it, and attempts are now being

made to form a joint-stock company to work it. It is, however, remarkable, that those who have been most prominent in expressing their opinions of the value of the undertaking, are evidently very disinclined to enter upon it commercially, and how it will end we are unable to say. At present the local authority is obliged to continue the farms for sanitary purposes, and this they will do until the hoped-for Company is formed, and they are relieved from their responsibilities.

At Norwood the rent paid by the local Board is £10 per acre for the new land which they have taken, and £400 per annum for the thirty-seven acres already under irrigation, and the wages and general expenses, exclusive of the interest of money for laying out the land, and for wages of the surveyor, are about £300 a year, and the returns for the crops sold are about £750 a year; but the profits depend, as elsewhere, upon the very precarious demand for rye grass, which must be sold when it is ready to cut, let the price be what it may, or it will rot upon the ground; and hence the price of it ranges from a shilling to threepence a rod of six square feet. Anything which disturbs the demand, as the cattle plague, for instance, or a plentiful crop of hay, reduces the value of the grass to a nominal sum; but of this we shall have more to say in our concluding remarks, when we review the whole of the facts of the subject and generalize upon them.

CRAIGENTINNY SEWAGE MEADOWS,

NEAR EDINBURGH.

THESE meadows have long been notorious, as the most filthy and offensive plots of cultivated ground in Great Britain. They are also remarkable for their so-called extreme fertility in producing the largest produce of a coarse, rank, and washy grass, which, like brewers' grains, is only fit for the food of milch cows, pent up in the close sheds of a town dairy, where quantity and not quality of milk is the desideratum.

They are situated about two miles to the east of Edinburgh, upon the sandy shore of the Frith of Forth, and they have an area of about 250 acres. The sewage is poured upon them from an open sewer called the "*Foul Burn,*" which drains a district in Edinburgh with about 80,000 inhabitants, where water-closets are not in general use. The *Burn* runs eastward and northward from the city, and passes through a small sewage farm of about thirty acres (the Lochend farm), twenty of which are in permanent grass, and the rest in Italian rye grass. The tenant of this farm takes the sewage when he likes, and he also takes as much of it as he likes, and the rest of it runs eastward in the open *Burn* to the Craigentinny meadows, and thence, if not wanted, to the sea. As it passes

through the meadows it is distributed upon them in the most profuse manner, rendering the ground a swampy sewage morass ; in fact, the effluent water which runs off by many channels, and trickles away to the sea-shore, is as foul as it can well be. The smell from the open *Burn* and the swampy meadow is so powerful that it is offensive to the whole neighbourhood. The soldiers at the neighbouring cavalry barracks at Piershill complain of it as a serious nuisance, and say that at times it is quite sickening. Dr. Ligertwood, the surgeon of the 8th Hussars, attributes the absence of disease among the soldiers while stationed there, in 1868, to the fact that the site of the barracks is open, and well exposed to the sea breeze, which counteracts any evil influence from proximity to such fields, and thus, he says, they maintained their health "in spite" of the nuisance.

But although the quantity of sewage thus put upon the land is enormous, yet a large amount of it is still permitted to flow into the sea unutilized, notwithstanding that there is plenty of land at a slightly higher level upon which it might be distributed. Looking at the fact, as set forth in the constantly reiterated statements of those who speak of the large profits of the Craigentinny farm, that from £24 to £36 an acre are realized from the use of sewage upon a barren waste, it is remarkable, at first sight, that any of the sewage should be allowed to run to waste while there is an acre of land to utilize it. The paradox, however, is easily explained, for as there is but a limited demand for Italian rye grass, which is the only crop that can be profitably cultivated, it would be folly to produce more of it than can be sold. At the time of our visit to the meadows, in 1866, there were acres upon acres of the grass rotting upon the ground, because the cattle plague had killed the cows, and the demand for such fodder had ceased. The sewage, therefore, was running away to sea by its natural channel, and the ground was almost entirely abandoned. We had great difficulty in finding the man who had charge of it, and he told us that

they would gladly give the grass to anybody who would cut it and carry it away, and that during the year they had not realized above £7 an acre for even the best plots of the ground.

The soil of the meadows at the lower part is almost entirely sand, reclaimed from the sea-shore, but at higher levels it is good arable land. A little of the higher land (about eight acres) is irrigated by means of a steam pump but as we have already said, there is no inclination to utilize any more of this land, although it is not more than ten or fifteen feet above the level of the burn, because of the limited demand for the succulent produce ; the sewage, therefore, is allowed to run to waste, and the land is cultivated with ordinary manures.

It will be evident from this that the Craigentinny meadows are not examples of what *should* be done with sewage, but rather of what *can* be done with it, when all sanitary considerations are out of the question, and when, at the will of the tenant, the sewage can be utilized or not. But how would it be if there was no neighbouring sea-shore for the reception of the sewage, and the purification of it by proper irrigation were an imperative necessity? The answer is self-evident, for the rank grass would have to be sold in an overstocked market for what it would fetch, and the Craigentinny Meadows would then be examples of the yearly loss which a local authority was compelled to incur in disposing of their sewage by irrigation, so as to obtain a pure effluent water.

TREATMENT OF

SEWAGE BY FILTRATION.

Attempts have frequently been made to purify sewage by means of rude processes of filtration and spontaneous precipitation, but they have never been successful unless the effluent sewage could be discharged at once into the sea, or into a tidal stream, for none but the grosser particles of suspended matter can be thus separated from sewage.

A *coarse filtration of sewage* is generally practised before it is distributed upon the land for irrigation. At Aldershot and Rugby, for example, the sewage is strained through perforated planks, with apertures of about three-quarters of an inch in diameter, but the purifying effect is not considerable, for the amount of suspended matter in the Aldershot sewage was only reduced from 43·77 grains per gallon to 35·01, the organic matter of which was 14·02 grains and 8·77 grains respectively. Even with a more elaborate system of filtration, as was lately practised at Merthyr Tydvil, where the sewage passed through a filter of course iron slag about three feet thick, and then through a small filter of coarse vegetable charcoal, the suspended matters were reduced from 169·81 grains per gallon

to 32·31 grains, and the soluble matters were not at all affected. In this case the flow of sewage was about 915,000 gallons per day, from a district with a population of about 50,000 persons; and as the sewage flowed through a drain nearly four miles in length, the suspended matters were completely disintegrated before they arrived at the outfall at Troedyrhiew, where the sewage received a small quantity of caustic lime before it was passed through the filters of broken slag and charcoal. The slag filter was 219 feet long, 5 feet wide, and 3 feet deep, and the charcoal filter which succeeded it was 7 feet long, 3 feet wide, and 2 feet deep. Samples of the sewage were taken before it entered the filters and after it left them to be discharged into the River Taff, and the following are the results of the analysis :—

Constituents per gallon.	Raw sewage.	Effluent water.
	Grains.	Grains.
Solid matter in solution . .	47·27	33·07
Chloride of sodium . .	7·19	5·76
Organic matter . . .	11·23	6·94
Ammonia	2·240	1·582
Ditto organic . . .	0·159	0·161
Nitrogen as nitrates, &c. .	0·000	0·000
Oxygen required to oxydise	1·231	0·711
Matters in suspension . .	169·81	32·31
Organic matter . . .	72·64	14·11
Mineral ditto . . .	97·17	18·20

Mr. Strang, of Glasgow, has designed an apparatus for filtering the whole of the liquid matters discharged from a water-closet. It consists of a box about three feet long, eighteen inches broad, and four feet deep, having a filtering medium composed of the refuse coal ashes of the house, the filtration being upwards, so that the solid matters are

retained in the lower part of the vessel, while the liquid portion passes away through the ashes. The apparatus may be placed in connection with the closet or the outfall drain from the house, and the solid matters can be removed from it when necessary. The apparatus has been tried at a public institution in Glasgow with about 200 inmates, and has, apparently, worked very well. Samples of the effluent water which we have examined have been very free from suspended matters, and Dr. Anderson reports of it that so far as deodorizing and decolourizing the fluids are concerned it is perfectly successful, although it allowed the soluble portions of the urine to escape untouched. The composition of the effluent liquid and the retained solids was as follows :—

Constituents per gallon.	Effluent liquid.	Retained solid.
	Grains.	Grains.
Total solid matter . .	13·20	1136·00
Organic matter . . .	3·12	269·92
Fixed salts . . .	10·08	166·08
Ammonia	0·19	59·81
Phosphoric acid . .	0·40	57·93

He reports that when the retained solids are mixed with about their own bulk of ashes, they form a solid compost, which is worth, as far as the ammonia, phosphoric acid, and alkaline salts are concerned, about 9¼d. per ton, but that by an improvement of the apparatus a good deal of the superabundant water might be got rid of, so that the retained solids might be procured in a more concentrated state.

The late Mr. Austin, of the Local Government office, was of opinion that sewage might be purified by means of portable filters placed in the course of the sewers, each filter receiving the sewage of about 3,000 persons. In this manner the solid constituents of the sewage would be received into the filters and so retained before they had

become disintegrated by the mechanical action of the stream, or by chemical decomposition ; and when great purity is required, he proposed that there should be a second, or even a third or fourth subsidiary moveable filter packed with broken clinkers, breeze, or gravel, and a layer of charcoal ; and he enumerates the following as the advantages of this method, namely :—

"1st.—The filtration is easily accomplished, and the greater part of the fertilising ingredients are retained in the solid state in the manure box.

"2nd.—The solid sewage, confined in a portable vessel and surrounded by a deodorizing medium, can be taken from the drains in the course of a few minutes and conveyed without nuisance to the place destined to receive it.

"3rd.—The fluid part rendered innocuous may be allowed at once to escape into the nearest water-way, thus dispensing with the construction of large and costly conduits for its conveyance to distant outlets."

As regards the profits of the system he considered that the solid manure would freely sell at the rate of 2s. per individual per annum, and that with 2s. 6d. per head per annum for the dust and refuse of a town, there would be a return of 4s. 6d. per head per annum ; and allowing 3s. 3d. as the cost of expenses, &c., in working the system, it ought to yield a clear profit of 1s. 3d. per head of the population per annum, instead of the usual loss on interest of capital sunk in irrigation works. Experience, however, has shown that the filtration of sewage is not successful or satisfactory, and it has been invariably abandoned wherever it has been tried, as, for example, at Rugby and Birmingham, where sand filters were used, and at Chelmsford and Bilston, where clinkers and ashes were employed ; for if the filtering material be fine in its texture it speedily clogs, and if it be coarse, it fails to remove other than the grosser particles of sewage.

TREATMENT OF

SEWAGE BY SUBSIDENCE AND FILTRATION.

As an example of the effects of *spontaneous precipitation*, the sewage works at Birmingham may be referred to. They are situated at Saltley, about three miles to the east of Birmingham, and they consist of four sets of subsiding tanks in series, with weirs and floating boards to keep back the suspended solid matters. The arrangement of the tanks is as follows :—The sewage, which amounts to about 17,000,000 gallons a day, is discharged from the main sewer, through five openings, into a subsiding tank about ninety feet wide and fifty feet long ; it then flows over a weir, guarded by floating boards, into a second tank of the same dimensions ; and then it flows over a like weir into a third tank which is 150 feet long and 30 feet wide ; from which it passes over another weir into the fourth subsiding tank, which is about three times the capacity of the last ; and, finally, it flows over a long surrounding weir, which is only half an inch below the level of the sewage water, into a channel which conveys it into the River Rea, at its junction with the River Tame. In this

manner a large portion of the suspended matter of the sewage is retained, for it takes about two hours to pass through the whole series of tanks, and during this time a considerable subsidence of the insoluble matters must necessarily occur, but still the effluent water is very offensive, and is a cause of serious nuisance to those who have an interest in the river below the outfall. There are two sets of these tanks at the works, and when one set has been in operation about a fortnight, it is so charged with sedimentary matter as to require cleansing, and then the other set is brought into use. The sedimentary matter, in the form of a black sludge, is removed from the tanks by means of buckets on an endless chain worked by steam power, and it is run into properly prepared pits, where it consolidates by evaporation and soakage, so that in the course of twelve months it is fit for sale as manure. It then contains about 50 per cent. moisture, and 17 per cent. of organic matter, and the farmers take it at the price of one pound sterling for a barge-load of from 25 to 30 tons. The whole of the works are in a very unsatisfactory condition, and are a serious nuisance to the neighbourhood.

The following was the composition of the raw sewage, and of the effluent water, at the time of a recent visit to the works :—

Constituents per gallon.	Raw Sewage.	Effluent Water.
	Grains.	Grains.
Solid matter in solution	89·00	82·11
Chloride of sodium	41·54	20·77
Organic matter	13·89	9·36
Ammonia	2·52	2·44
Ditto organic	0·45	0·38
Nitrogen or nitrates	0·00	0·00
Oxygen required to oxydise	1·65	1·12
Matters in suspension	68·36	25.86
Organic matter	29·16	11·04
Mineral ditto	39·20	14·82

The *combined system of sedimentation and filtration* is scarcely more successful. At Coventry, where it has been for a long time in use, the sewage from a population of 43,000 persons, is received into a tank about 150 feet long and 49 feet wide, and 9 feet deep. From this it passes through a lateral filter of coarse gravel running the whole length of the tank, and is received into a second tank of the same dimensions. From this it passes through a similar lateral filter of finer gravel into a third tank, and thence it passes over a weir into the tail brook. There are two sets of these tanks, and each works about a month, when the sedimentary sludge is taken out and mixed with the ashes and sweepings of the town, and sold for manure at the rate of 2s. per load of a cubic yard. The works were nearly self-supporting, but the purification of the sewage was very imperfect, and hence it is to be abandoned.

At St. Thomas, which adjoins Exeter, the local Board have adopted a similar method of defæcation. The sewage, which amounts to about 200,000 gallons a day, flows to the works, which are about a quarter of a mile from the town, and there it receives a graduated dose of crude carbolic acid (about three-quarters of a gallon of carbolic acid, with a little lime and 250 gallons of water being so used every day). The sewage then flows into two subsiding tanks, and after passing through a coarse strainer of perforated iron, it is filtered through a lateral filter of coarse gravel about two feet thick, which forms the side boundary of the tanks. The effluent sewage is still turbid, but the presence of the carbolic acid completely prevents putrefactive decomposition, so that the effluent sewage passes alongside of the railway in an open channel for about a mile and a half, to the outfall iuto the tidal part of the River Exe, without causing the least annoyance. The tanks and filters are in duplicate, so that when one requires emptying the other is in use. Each tank works for about six weeks, and then the sedimentary matter is removed and mixed with the town refuse, and sold for manure at the rate of 5s. a ton. About 400 tons are thus

obtained from the tanks every year, and as the effluent water is not a cause of offence the operations are successful. The effect of the carbolic acid in preventing the putrefactive decomposition of both the sludge and the effluent water was most remarkable, for even in the hot weather of last summer there was no offensive smell at the works.

At Uxbridge an attempt was made to purify the sewage of 10,000 persons by subsidence and subsequent filtration through charcoal before it was discharged into the River Colne. The sewage, which amounted to about 135,000 gallons a day, flowed to the works by gravitation, and after passing into a subsiding tank about 50 feet long and 15 feet wide and 4·5 feet deep, where the coarser solid matters were deposited, it was strained through a grating, and then filtered through twelve boxes of coarse vegetable charcoal, each four feet long, and two wide, and one deep. There were two sets of these filters, which were worked alternately, and when the filter ceased to act, the charcoal, together with the solid matters, was removed and mixed with the town refuse and sold for four shillings per cubic yard. The process was so imperfect that it was abandoned in the year 1857, in consequence of a motion to the Court of Chancery for a breach of the injunction granted in 1855, restraining the Local Board of Health from discharging sewage into the River Colne, " otherwise than in a state deodorised and free from anything offensive." The original sewage, at the time of our examinations in 1857, contained forty-one grains of solid matter per gallon, of which 6·75 were organic ; and the filtered sewage contained thirty-six grains per gallon, 5·4 of which were organic. The filters, therefore, removed about five grains of solid matter, of which 1·35 were organic.

Very dilute sewage, with only a small quantity of suspended matter, is still less affected by filtration, unless the filters are well constructed. An example of this came under our notice, in 1866, at the little town of Alton in Hampshire. The population at that time was about 3,800, and the average quantity of sewage was 60,000 gallons a

day, the town being very well sewered and drained. On its way to the works, which are on the banks of the River Wey, about 1,000 yards from the town, the sewage received nearly sixteen times its volume of subsoil water, making a total quantity of not less than 1,000,000 gallons of diluted sewage. This was received at the works into two large subsiding tanks, each twenty feet long and seven wide, divided into two compartments by floating planks which kept back the scum. After the separation of the coarser suspended matters, the sewage passed through a series of five filters, composed of coarse shingle, and then it was discharged into the river. The chief constituents of the sewage before and after this treatment were as follows :

Constituents per gallon.	Before Treatment.	After Treatment.
	Grains.	Grains.
Solid matter in solution . .	25·3	24·9
Organic matter . . .	4·8	3·3
Mineral ditto . . .	20·5	21·6
Oxygen required for oxydation	0·300	0·225
Matters in suspension . .	1·7	1·4
Organic matter . . .	1·1	1·0
Mineral ditto . . .	0·6	0·4

The scum was removed daily, and altogether it was found that about ten tons of solid matters were thus separated from the sewage every month.

TREATMENT OF

SEWAGE BY CHEMICAL PROCESSES.

THE offensiveness of sewage and cesspool matters, as well as the more or less exaggerated estimate of their agricultural value, have served at all times as a powerful inducement for the discovery and application of some simple process whereby the most important constituents of these matters might be so disinfected and consolidated as to render them not only inoffensive to the public, but also useful to agriculture and fit for commercial purposes. Chemists of great celebrity, as well as the merest dabblers in experimental science, have devoted attention to the subject, and have proposed the use of all kinds of materials for the purpose in question. A glance, indeed, at the following table, which exhibits most of the suggestions for the treatment of these matters over a period of nearly a hundred years, will show how completely the subject has been explored, and how futile have been the results. Almost every description of waste product, as well as many rarer chemical compounds, have been vainly resorted to, and made the objects of unprofitable patent inventions. The caustic alkalies, mineral acids, metallic salts, empyreumatic oils, spent tan, vegetable charcoal, trade and

household refuse, and all sorts of worthless substances have been successively and often repeatedly used for this purpose.

List of substanees proposed to be used for the disinfection and utilisation of sewage and eesspool matters.

Name of substances.	Inventor.	Date
Acetate of lead and proto-sulphate of iron . .	Deboissieu.	1762
Chlorine	Hallé.	1785
Quick lime. . . .	Estienne.	1802
Powdered charcoal . .	Giraud.	1805
Chlorine and chloride of lime	Guyton Morveau.	1805
Ashes	Chaumette.	1815
Sand	Duprat.	1818
Sulphate of iron . .	Briant.	1824
Chloride of soda . .	Labarraque.	1824
Waste chloride of manganese	Payen and Chevalier.	1825
Sulphate of lime . .	Siret.	1827
Animal charcoal . .	Frigerio.	1829
Peat	Guibourt & Sanson.	1833
Charcoal and calcined marl or river mud . . .	Pottevin.	1835
Sulphates of iron and zinc with tan and tar . .	Siret.	1837
Earth, lime, and waste substances	Rossier.	1837
Peat ashes	D'Arcet.	1840
Metallic oxides and carbon .	Krafft & Suequet.	1840
Chloride of zinc . . .	Sir Wm. Burnett.	1840
Schist coke . . .	Hompesch.	1841
Trade refuse, charcoal, and ashes	Albert.	1842
Powdered lignite . .	Jourdan.	1843
Impure alum . . .	Siret.	1843
Sulphate of zinc, charcoal, and clay . . .	Gagnage & Regnault.	1844
Persulphate of iron . .	Baronnet.	1845
Schist coke . . .	Du Boisson.	1845
Chlorides of iron and zinc .	Dubois.	1846
Lime and precipitating tanks	Higgs.	1846
Nitrate of lead . . .	Ledoyen.	1847

Name of substance.	Inventor.	Date.
Waste salts of iron, lead, zinc, &c., with pyrolig-matters, ashes, &c. .	Brown.	1847
Pyrolignate and perchloride of iron	Ellerman.	1847
Impure chloride of manganese	Young.	1847
Dried sea-weed, lime, and sulphate of lime and zinc	Salman.	1848
Peat charcoal . . .	Rogers.	1848
Charcoal, soot, mineral salts, &c. . . .	Legras.	1849
Spent tan, carbonised .	Tarling.	1850
Fresh bark, sulphate of iron, and peat charcoal . .	Angely.	1850
Metallic sub salts, as of iron, alumina, &c. . .	Browne.	1850
Milk of lime and collecting the deposit . . .	Wicksteed.	1851
Acids and metallic salts, and filtrations through charcoal, clay, peat, gypsum, &c. . . .	Dover.	1851
Lime, sulphates of alumina, and zinc and charcoal .	Stothert.	1852
Lime, magnesian earth, sulphate of zinc or iron and vegetable charcoal . .	Gilbee.	1852
Sifted ashes, breese, or peat charcoal . . .	Perks.	1852
Sulphate of zinc, potash, alum, and sand, with waste tan, ashes, lime, soot, &c. . . .	Pinel.	1853
Metallic sulphates, metallic chlorides, or charcoal and magnesian salts . .	Herapath.	1853
Salts produced in working galvanic batteries . .	Dering.	1853
Peat or bog earth containing salts or oxides of iron .	Dimsdale.	1853
Peat and other charcoal and chloride of sodium, &c. .	Macpherson.	1853

Name of substance.	Inventor.	Date.
Animal charcoal, alum, carbonate of soda and gypsum	Manning.	1853
Magnesia and lime with sulphurous and carbolic acids	Smith & McDougall.	1854
Lime and finely-divided charcoal . . .	Wicksteed.	1854
Boghead coke . . .	Herapath.	1854
Soft sludge from alum works with lime and charcoal .	Manning.	1854
Peat charcoal carbonised with oil of vitriol . .	Longmaid.	1855
Alum schist or shale, and other aluminous minerals, with lime and charcoal .	Manning.	1855
Manganates and permanganates	Condy.	1857
Superphosphate of lime with magnesia and lime . .	Blyth.	1858

Hardly anything can be more illustrative of the reckless way in which inventors endeavour to apply their knowledge, without first ascertaining what has been already done in the matter, and how far it has been found successful. Quicklime, for example, as well as the various forms of charcoal, and the salts of iron and alumina, have again and again been the subjects of patent invention. But, besides this, there have been many patents for the most elaborate treatment of sewage and nightsoil. White, in 1854, proposed to carbonise nightsoil in a close retort, and to mix the products with dried blood, dried nightsoil, superphosphate of lime, wood ashes, &c., and so to form them into a manure. Bardwell, in 1853, and Littleton as well as Anderson, in 1854, proposed to utilise the ammonia of sewage by processes of evaporation and subsequent absorption; and Noone, in 1865, actually distilled the sewage, and obtained a liquor which was charged to the extent of 38·75 grains of ammonia per gallon; but, as in practice it required about 1,000 gallons of sewage to furnish this quantity of liquor, the value of which was only about five

farthings, the process was soon abandoned, although it was most hopefully entertained by the authorities of Hastings, where it was fully tested on the sewage of the town. Patents have also been taken out for the speedy desiccation of the solid matters precipitated from sewage, as by Perks in 1852, Needham in 1853, Wicksteed in 1854, Kite in 1854, Noone in 1864, &c.

In connection with this subject, it may not be out of place to refer to the experiments of the late Dr. Davy on the deodorising power of different substances on nightsoil. He took 125 grains of nightsoil, and found that the following were the proportions of the several substances required to deodorise it :—Volatile oils, including naphtha, gas tar, and creasote, from one to two grains ; fixed oils, from four to thirteen grains ; a mixture of vinegar and creasote, one grain ; vinegar alone, eight grains ; pyroligneous acid and nitro-muriatic acid, four grains ; chromic acid mixed with strong sulphuric acid, eight grains ; sulphuric acid alone, twenty-two grains ; a saturated solution of euchlorine, forty-one grains ; ditto of chlorine, ninety-four grains ; ditto of chloride of lime, forty-seven grains ; but sulphate of iron, chloride of zinc, muriatic acid, and bichromate of potash had little or no deodorising power.

The following are the results of experiments made by Dr. Letheby in the year 1858, when he reported to the City authorities on the subject of sewage and sewer gases.

Quantities of different disinfectants required to deodorise ordinary London sewage.

Deodoriser.	Price.	Grs. required per gallon of Sewage.	Results as to Deodorisation.	Cost per 100,000 gals. of Sewage. £	s.	d.
Quicklime - -	10s. per ton.	12	Incomplete.	0	0	9
Chloride of Lime -	£15 ,,	8	Complete.	0	15	4
McDougall's Powder	£12 ,,	40	Incomplete.	3	1	3
Peat Charcoal - -	£3 5s. ,,	150	Ditto.	3	2	3
Condy's Liquid -	1s. per gal.	150	Complete.	10	14	4
Dale's do, - -	6d. ,,	313	Incomplete.	11	3	7
Ledoyen's do. - -	4d. ,,	1,000	Ditto.	23	16	4
Ellerman's do. - -	9d. ,,	470	Ditto.	25	3	6
Sir W. Burnett's do.	4s. ,,	100	Ditto.	28	12	0

The several liquids used in these experiments had the following strength :—

	Sp. Gr.	Grs per gal	Of following.
Condy's Liquid	1,055	4,357	Permanganate of Potash.
Dale's do.	1,470	64,827	Perchloride of Iron.
Ledoyen's do.	1,160	8,120	Nitrate of Lead.
Ellerman's do.	1,443	43,434	Muriate and Pyrolignate of Iron.
Sir William Burnett's do.	1,594	60,031	Chloride of Zinc.

In those cases where the deodorisation was incomplete. the peculiar smell of sewage remained—sulphuretted hydrogen, and, except in the case of quick-lime, ammonia being the only volatile matter removed. In all cases the substances were added until subsequent decomposition was entirely prevented, or until they ceased to remove any more of the sewage smell ; and no doubt in many cases they were added in much larger proportions than would be necessary in practice on a large scale, especially where the precipitate occasioned by the substance was quickly removed from the sewage. This, indeed, has been fully proved by subsequent experiments and inquiries.

The thick matters of cesspools, and of stagnant sewers were found to require about a twentieth part of their weight of chloride of lime to deodorise them, and the corresponding proportions of the other deodorisers.

We will now examine the practical results of the various disinfecting and defæcating processes on a large scale, as at the several sewage works where they have been used.

PRECIPITATION OF
SEWAGE WITH CAUSTIC LIME.

As far back as the beginning of the year 1802, M. Lewis James Armand Estienne obtained a patent for the use of lime as a means of disinfecting and consolidating human excrement; but it was not until the year 1844 that caustic lime was employed for the precipitation of sewage. In that year Dr. Clark, of Aberdeen, and Mr. John Graham, of Manchester, resorted to it for the purpose of purifying the refuse water from the Mayfield Print Works at Manchester, and the results were so satisfactory that the process was immediately adopted on a large scale. It was also used at that time for the purification of the River Medlock, which receives the sewage and trade refuse of Manchester, but although successful, the cost of the process was considered to be a hindrance to its adoption, for Dr. Clark was of opinion that it would require about a ton of lime daily to defæcate the whole of the water of the river. In the autumn of 1854, when the state of the river was so bad as to create alarm for the public safety, the process was again recommended by Dr. Crace Calvert, of Manchester, who found, from experiments made at the request of the Sanitary Association, that the black and fœtid water of the river could be completely purified, by adding to it from two to three grains of hydrate of lime per gallon of water, and allowing it to settle. Taking the average of five successive days' experiments, the following were the results :—

Constituents per gallon.	Original Water.	Effluent Water.
	Grains.	Grains.
Dissolved matters . . .	32·00	25·76
Organic matter . . .	8·54	3·50
Mineral ditto . . .	23·46	22·26
Oxygen required for oxydation	—	—
Matters in suspension . .	6·65	0·00
Organic matter . . .	3·57	0·00
Mineral ditto . . .	3·08	0·00

From which it is evident that the lime precipitated not only the suspended matters, but also a large proportion of the dissolved organic matter, leaving only about three and a-half grains of this impurity in a gallon of the water. The precipitate was found to subside very rapidly, the supernatant water being perfectly clear, colourless, and inoffensive.

This method of treatment resulted from the patent obtained by Dr. Clark in 1841, for softening and purifying water for domestic purposes by means of caustic lime, it having been found that the flocculent precipitate thus produced removed from the water a notable quantity of dissolved organic matter, it being a property of such precipitates to aggregate and carry down not merely the suspended matters of foul water, but also a considerable amount of the dissolved impurities. This fact was more fully developed in the year 1846, when Mr. William Higgs obtained a patent for the treatment of sewage in subsiding tanks or reservoirs, by means of "chemical agents for the purpose of precipitating the solid animal and vegetable matters contained therein, hydrate of lime, commonly termed slacked lime, being preferred ;" and five years later a like patent was obtained by Mr. Thomas Wicksteed, who proposed to manufacture manure from sewage or other

liquids containing fertilising matters, by mixing them with milk of lime, collecting the deposit, and submitting it to certain centrifugal drying machinery, "whereby the whole or nearly the whole of the moisture is driven off, and the manure or fertilising matter is obtained in a state commodious for transport." Both of these patents were put into operation on a large scale by the patentees, with considerable sanitary success, although the commercial results were not encouraging. At Tottenham, for example, where Mr. Higgs's process was tried, and at Leicester, where Mr. Wicksteed's was adopted, the whole of the sewage of the two places was submitted to treatment with lime, and the results were most satisfactory, as regards the purification of the sewage, and the marked improvement of the neighbouring streams into which the purified sewage was discharged. In fact, the Tottenham Local Board of Health were so pleased with the process, that in the early part of 1857 they published a testimonial to the effect that Mr. Higgs was treating in a most satisfactory manner the sewage of from thirty to forty miles of sewers, and discharging the supernatant water in a comparatively pure state into the River Lea, so that the Board was thus enabled satisfactorily to sewer and drain their populous district, and dispose of the sewage without annoyance to anyone. At Leicester also, in 1858, three years after Mr. Wicksteed's works had been established, the River Soar had become changed from a most foul and pestilential stream into a comparatively pure river, for before the sewage was purified by Mr. Wicksteed's process the water of the river was black with decomposition, all the fish and aquatic plants had been killed, and persons exposed to its influence were constantly ill. At the Belgrave Mill, which is just below the point where the sewage enters the river, the foulness of the stream was such that in summer time the water of the mill-dam appeared to boil with putrefaction, and the stench was intolerable. So large, indeed, was the quantity of sulphuretted hydrogen evolved from the water that the silver in the men's pockets turned black in

a few hours, and, as might be expected, those who worked at the mill were constantly affected with diarrhœa, and rapidly fell off in health ; one man only, out of thirty, in eighteen years had been able to withstand the effects of the effluvium, and he it was who gave us an account of the matter. But soon after the lime process had been adopted the river presented an entirely different appearance, for aquatic plants had begun to flourish, the fish had returned, the black mud had ceased to accumulate, and the mill-dam was no longer offensive. All along the stream the people spoke of the change with satisfaction, for the process had evidently fulfilled the requirements of the Local Act of Parliament, which demands that the sewage water discharged into the river from the works shall not occasion a nuisance or be injurious to the health of those who live or are employed upon the banks of the stream.

At Tottenham, at the time of our visit in 1858, the sewage was dealt with in a comparatively fresh state, so that when it arrived at Mr. Higgs's works it was neither decomposed nor disintegrated. The average quantity of sewage amounted to about 175,000 gallons a day, and this was furnished by about 10,000 persons. On reaching the works it was first strained and then treated with twelve grains of lime, in a creamy condition, to every gallon of sewage, the amount of lime used per week being just one ton to 1,225,000 gallons of sewage, and the product of dry manure or precipitate thus obtained was from four to five times the weight of the lime used.

At Leicester the quality of the sewage was exactly similar to that of ost large towns, except that it was often tinted with dye-stuffs, the solid matters being much disintegrated and far advanced in putrefactive decomposition. The population of Leicester, in 1858, was about 65,000, and the amount of sewage about 2,000,000 of gallons a day. The greater part of this was conducted to the works, and treated with lime—the proportions being from three to sixteen grains per gallon of sewage. In the summer, when in full work, the last named quantity was used ; but in winter, when

the process of putrefaction is checked by cold, the former proportion was employed; and the amount of dry, solid precipitate obtained was from three to four times the weight of the lime used. In fact, when twelve grains of lime were employed, as at the time of our visits to Leicester and Tottenham in 1858, the following were the amounts of organic and mineral matters precipitated from each gallon of sewage :—

Constituents per Gallon.	Leicester.		Tottenham.	
	Raw Sewage.	Effluent Water.	Raw Sewage.	Effluent Water.
	Grs.	Grs.	Grs.	Grs.
Dissolved Matters	70·00	66·99	54·50	48·99
Organic ...	13·49	10·65	9·49	8·01
Mineral ...	56·51	56·34	45·01	40 98
Ammonia ...	2·52	2·61	2·60	2·84
Suspended Matters.	19·15	1·40	39·99	1·69
Organic ...	5.50	0·49	14.53	0.37
Mineral ...	13·65	0·91	25·46	1·32

So that in the case of Leicester sewage the precipitate obtained from a gallon of sewage, with twelve grains of lime, amounted to nearly forty-two grains, of which about eight grains were organic matter ; and in that of the Tottenham sewage it amounted to nearly sixty-five grains per gallon, of which about sixteen grains were organic. These results accord very closely with experiments made at that time in the laboratory with ordinary London sewage, and from which it was ascertained that with twelve grains of lime per gallon of sewage, from the several City sewers, the average amount of precipitate obtained was about 54·5 grains, of which 21·1 were organic. This consisted of all the suspended matters of the sewage, amounting to 38·2 grains, and about one-fourth of the dissolved organic matter, together with the lime which was converted into carbonate and phosphate. The particulars of these experiments are shown in the following table :—

Proportions of Organic and Mineral matters precipitated from a gallon of London Sewage with 12 Grains of Lime.

Sewage from	Original Sewage.				Precipitated with 12 grains of lime.		Soluble organic matter removed.	Do. do. still in solution.
	Dissolved.		Suspended.					
	Organic.	Mineral.	Organic.	Mineral.	Organic.	Mineral.		
	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
The Fleet Sewer ...	11·60	30 00	14·40	12·60	17·34	29·71	2·94	8·66
London Bridge do. ...	20·96	37·09	7·04	15·40	12·46	27 69	5·42	15·54
Dowgate Dock do. ...	27·31	38·36	16·64	13·26	23·94	26·52	7·30	20·01
Irongate do. ..	11·20	65·01	15 80	16·32	18·81	29·07	3 01	8·19
Paul's Wharf do. ...	21·79	51·35	17 21	32·21	23·18	44·69	5 97	15·82
Whitefriars Dock do. ...	3·53	23·02	9·59	4 89	10·45	16·97	0·86	2·67
Custom House West do.	9·22	64 30	36·28	42·21	39 02	50 01	2·74	6·48
Custom House East do.	20·19	37·82	12·13	14·82	17·55	24·97	5·24	14·95
Hambro' Wharf do. ...	14·24	32·79	4·26	12·75	7·99	25·03	3·73	10·51
Wool Quay do.	10·76	23·84	35·04	46·41	37·85	59·32	2·81	7 95
Average of all	15·08	40·66	17·06	21·09	20·86	33·39	4·20	11·08
	$\underbrace{\qquad}_{55·74}$		$\underbrace{\qquad}_{38·15}$		$\underbrace{\qquad}_{54·25}$			

The flocculent precipitate which is thus formed settles at the rate of from one to two inches per minute, and in the course of an hour it subsides to about the fortieth part of the bulk of the original fluid, leaving a clear supernatant liquor, which is comparatively inoffensive, and which may be admitted into a running stream of good water without causing offence. In a sanitary point of view the careful precipitation of sewage with lime has undoubtedly been very successful, although it has not been found profitable commercially; for the precipate is chiefly composed of carbonate of lime and non-nitrogenous organic matter.

As first the patentees of this process were so sanguine of commercial success, and entertained such extravagant opinions of the fertilising power of the dried sewage precipitate, which they called "sewage guano," that great and unnecessary expense was encountered in the construction of the works at Tottenham and Leicester. They were built, in fact, with a view to commercial profit rather than for sanitary purposes; and, therefore, as soon as it was found, from experience, that the manufactured product had little or no agricultural value, and that the undertaking was unprofitable, the works were abandoned by the patentees, and transferred to the local authorities. In the case of Tottenham, the machinery and plant erected at great cost by Mr. Higgs were purchased at an almost nominal price by the local board, who could, therefore, have well afforded to use them properly for sanitary purposes; but instead of this, although ample proof had been furnished of their sanitary capabilities (as witnessed by the testimonial of the Board to Mr. Higgs in the month of February, 1857), yet they were so neglected and improperly managed as to have become at last a mere pretence of the objects for which they were designed and employed. The contrast, indeed, between the condition of things in 1857, as described in the testimonial of the Board, and subsequently, was most marked; for at that

time, to use the language of the testimonial, "the supernatant water was discharged in a comparatively pure state into the river," so that "the Board, by these means, was able satisfactorily to sewer and drain their populous district, and dispose of the sewage without annoyance to anyone." Almost as soon, however, as the works had passed into the hands of the local authority, the process was so imperfectly conducted that the trustees of the River Lea were obliged to commence legal proceedings on account of the pollution of the river, and the nuisance created by the discharge of foul undefæcated sewage from the works; and this at last became so serious that an injunction was obtained to prohibit the offensive practice of the Board. In this manner the local authority became involved in expensive litigation, which might not only have been altogether avoided, but which, by being avoided, would have cost far less of the public money.

At Leicester, the sewage works, which were erected by the patentee and his company at a charge of from £30,000 to £40,000, were handed over to the local authority, according to the original agreement, free of cost; and from that time (1858) until now they have been used for sanitary purposes. At first they were managed with considerable success, so that the River Soar, which receives the defæcated sewage water, was maintained in a wholesome condition; but lately the process has been seriously neglected, and the river is fast becoming as foul as it was before the works were erected. At the close of the year 1867, when we last visited the place, the operations at the works were as follows:—The City of Leicester, which is well sewered and drained, had a population of about 90,000 persons, and the water supply was from twenty-five to thirty gallons per head daily. The sewage, therefore, ought not to have exceeded three millions of gallons per day, but in reality it amounted to from four to five millions of gallons a day, so that it was evidently much diluted with subsoil water.

The main sewer conveys the whole of the sewage to the works in the Abbey Meadows, which are on the bank of the River Soar, about half-a-mile from the town. On reaching the works the sewage is discharged into a well, from which it is lifted to a height of fifteen feet by two Cornish engines, each of 25-horse power, working night and day, according to the rate of flow. Each stroke of the pumps also delivers a graduated quantity of cream of lime, which mixes with the sewage in the channel into which it is pumped. It then passes into a trough about forty-five feet long, where it is violently agitated by means of revolving stirrers extending the whole length of the trough. This flocculates the precipitate occasioned by the chemical action of the lime upon the sewage, and so facilitates the subsidence of all suspended matters. It then flows into two subsiding tanks each sixty feet long and forty-five wide, having a shelving bottom which slopes from a depth of four feet at the sides to seventeen feet in the middle, where there is a channel or gutter with an Archimedian screw-race thirty-two inches in diameter, leading to a well provided with a Jacob's ladder of endless buckets. Here the great bulk of sedimentary matter is deposited, and the supernatant water flows over a cross weir into two other subsiding tanks, which are 120 feet long and forty-five feet wide, the bottoms being, as in the last case, on a lateral incline which slopes from a depth of six feet at the sides to nine feet in the middle, where there is a gutter that leads into the channel just mentioned. These tanks are covered; and the defæcated sewage leaves them by a shallow weir, about three-quarters of an inch below the surface, and falls into the main channel, which conveys it to the river. The total time of flow in the tanks is about four hours, and the lime was said to be used in the proportion of one ton per million gallons of sewage—that is, at the rate of 15·68 grains per gallon, but there is good reason for believing that this quantity was not actually being used. The main de-

positing tanks are worked alternately for about three weeks or a month, when the sewage is diverted, and the consolidated precipitate is driven forward to the well by the Archimedian screw, which rotates in the centre channel of the tank, and it is thence drawn up by the Jacob's ladder and discharged into a shoot which conveys it to the outside pits, where it drains and consolidates. The covered tanks continue in operation for about three months, when the sludge is scraped into the screw channel and so removed. The precipitated matter is exposed to the air in large quantity for a considerable time before it is sufficiently consolidated to sell for manure; and even then it contains from 30 to 40 per cent. of water. The following was the composition of the sewage before and after this treatment:—

Constituents per gallon.	Raw sewage.	Effluent water
	Grains.	Grains.
Solid matter in solution . .	60·33	48·33
Organic matter . . .	8·50	4·68
Ammonia	2·236	1·471
Ditto organic . . .	0·160	0·120
Nitrogen as nitrates . .	0·025	0·193
Oxygen required to oxydise .	0·969	0·750
Matters in suspension . .	11·45	4·54
Organic matters . . .	6 63	0·63
Mineral ditto . . .	4·82	3·91

The matters precipitated from the sewage by the lime, together with the carbonate of lime so formed, amounted to 36·72 grains per gallon, of which 14·93 were organic, and 22·39 mineral. This shows that the lime was not being used at the time of our visit in the estimated quantity of 15·68 grains per gallon of sewage, as this would have produced at least 32·82 grains of mineral matter.

The precipitate has been frequently analysed, and it generally contains in its dry state from one-third to nearly half its weight of organic matter, with about 2·5 per cent. of phosphate of lime, and about 1 per cent. of nitrogen, capable of yielding about 1·21 per cent. of ammonia. The value of the manure has been variously estimated by agricultural chemists at from 13s. 6d. to 17s. per ton; but the price realised at the works is only about 1s. a load. In its dry state, however, a good deal of it is sold to manure makers for 7s. 6d. per ton. The annual cost of conducting the works is about £1,400 a-year, of which £400 is returned to the Corporation by the sale of manure. This loss, which is inconsiderable in a sanitary point of view, and which might be much diminished by proper management, has led to greater and greater neglect in the conduct of the works, until now, as we are informed, the sewage is so imperfectly defæcated that the river is fast becoming as foul as it was in 1855, when the works were established by Mr. Wicksteed; and it is not unlikely that the foul condition of the river may be wrongly attributed to a failure of the lime process, *per se*, rather than to the ca re lessness and false economy of those who have had the management of it.

At Hertford the sewage works are managed by the New River Company, who are compelled by their Act of Parliament to deodorise and purify the sewage of the town before it is discharged into the River Lea, and this they accomplish by means of lime. The town has a population of about 7,000 persons, and being well sewered, the whole of the sewage, together with a large volume of subsoil water, is subjected to treatment at the works. The flow of sewage amounts to about 1,640,000 gallons a day, which is as much as 234 gallons per head of the population, or nearly ten times as much as the water supply. The distribution of the flow during the twenty-four hours is at the rate of about 70,000 gallons per hour in the day time, and 66,000 gallons in the

night. It runs by gravitation to the works, which are a little beyond the town, and is delivered into a subsiding tank 140 feet long and 20 feet wide, where it receives a dose of lime in a creamy condition, the lime being delivered by means of little buckets attached to a water-wheel which is turned by the effluent sewage, and in this way the quantity of lime is exactly apportioned to the rate of the flow of sewage. The subsiding tank is divided by two cross walls a little under the water line, and thus the sediment is kept back, while the supernatant water passes on to be discharged over a weir into a filter bed about twenty feet square, composed of six or seven inches of coarse gravel at the bottom, and three inches of fine sand above, and thence it passes into the effluent channel which is about a mile long, and so onwards into the River Lea at Ware Mill. The quantity of lime which was used at the time of our visit to the works in October, 1866, was about eight and a-quarter bushels per day, and to this were added 150 lbs. of chloride of lime, making a proportion of nearly two grains of lime and 0·64 of a grain of chloride of lime per gallon of sewage. The time or duration of the flow of sewage through the subsiding tank was about forty minutes, which is much too short for complete subsidence. The tanks and filters are in duplicate, the former being worked for three days, when the precipitate is removed, and the latter are cleaned out daily. The sludge or precipitate is placed upon a covered platform between the tanks, where it drains and consolidates ; and after a period of three or four months it is sold to farmers at the price of 2s. 6d. per load. In this manner about 12 cwt. of solid matters are removed from the sewage daily. The effluent water is a little turbid when it leaves the filters, but it soon becomes clear, so that after flowing along the out-fall channel for about a quarter of a mile, it becomes quite clear, and fish and aquatic plants are found in it in abundance. The composition of the sewage and the effluent water on three occasions in 1866 were as follows :—

Constituents per gallon.	August 26.		August 31.		December 13.	
	Raw sewage.	Effluent water.	Raw sewage.	Effluent water.	Raw sewage.	Effluent water.
Soluble matters . .	Grains. 26·95	Grains. 26·00	Grains. 29·30	Grains. 27·25	Grains. 30·33	Grains. 27·00
Organic . . .	1·70	1·00	1·95	1·20	5·35	2·51
Mineral . . .	25·25	25·00	27·35	26·05	24·98	24·49
Suspended matters . .	2·05	0·85	6·30	1·30	5·39	0·74
Organic . . .	1·05	0·35	3·25	C 60	0·71	0·24
Mineral . . .	1·00	0·50	3·10	0·70	4·68	0·50
Total . . .	29·00	26·85	35·60	28 55	35·72	27·74

When we visited the works in November, 1867, the quantity of lime was fourteen bushels a day, with one bushel of chloride of lime. This was in the proportion of 3·43 grains of lime and 0·33 of a grain of chloride of lime per gallon of sewage; and the composition of the sewage and effluent water were as follows:—

Constituents per gallon.	Raw sewage.	Effluent water.
	Grains.	Grains.
Matters in solution . . .	25·00	28·33
Organic matter . . .	2·50	1·25
Ammonia	0·343	0·457
Ditto organic . . .	0·480	0·560
Nitrogen as nitrate . .	0·026	0·091
Oxygen required to oxydise .	0·296	0·281
Matters in suspension . .	1·42	0·43
Organic matter . . .	0·72	0·17
Mineral ditto . . .	0·70	0·26

From which it was evident that nearly all the suspended matter, and about half of the dissolved organic matter, had been removed from the raw sewage by about three and a half grains of lime; and the chloride of lime, although amounting to only one third of a grain per gallon, had completely disinfected the sewage, and had also prevented the growth of the sewer fungus in the effluent channel, so that the water when it reached the river Lea was sufficiently pure to be admitted into it. In fact, the results of these and the Leicester works were so satisfactory in 1867 to Dr. Frankland, Dr. Letheby, and Dr. Odling, who visited them at the time in question, for the purpose of advising tho conservators of tho river Thames on the subject of the defæcation of sewage in the Thames Valley,.

that they reported of the process as follows :—"By this process the sewage was deprived of its suspended, and of a considerable portion of its dissolved, matter. But, as in the last case (irrigation), it was necessary that the defæcated sewage should be received into a considerable volume of running water to prevent secondary putrefactive change. At Hertford, the defæcated sewage water is filtered through coarse sand, and runs a distance of nearly a mile before it enters the river Lea. We remarked that, although it left the filter a little turbid from suspended lime, yet it became clear after it had run about a quarter of a mile in the conduit. In the performance of this process of defæcation, we are of opinion, from the results obtained at Leicester and Hertford, that—1st. The proportion of lime should not be less than one ton, and that there should also be used fifty-six pounds of chloride of lime per 1,000,000 gallons of sewage ; 2nd. That the mixture of the sewage with the lime and chloride of lime should be very complete, and that the mixture should be agitated so as to aggregate the suspended matters, and thus assist in the subsequent precipitation of suspended matters; 3rd. That the sewage when thus treated with lime should flow along two subsiding tanks in series—the first should be capable of holding at least an hour's flow of sewage, and the second of holding not less than four hours' flow. The tanks should be four feet in depth, and the overflow of the defæcated sewage should be by a weir only half an inch below the surface ; 4th. That there should be a double set of tanks for alternate working ; 5th. That the defæcated water should flow through a shallow, open conduit if not less than a quarter of a mile in length, before being received into a stream of freely running water, of not less than eight or ten times the volume of the defæcated sewage."

The conditions recommended by Dr. Letheby to the referees appointed by the Metropolitan Board of Works in

the year 1857 to enquire into the subject of the main drainage of the Metropolis were as follows :—

1. The lime should be used in a perfectly caustic state, and in the proportion if not less than twelve grains per gallon of sewage.
2. It should be well slaked with water, and got into a finely-divided or creamy state.
3. It should be thoroughly mixed with the sewage, and well agitated before it is set aside to deposit.
4. The precipitate should be allowed to settle with the liquid quiet for at least one hour.
5. The deposit should be consolidated and deprived of its water as speedily as possible.

And he further advised that, in summer time, the subsiding tanks should not be worked for more than two days without removing the deposit, as in warm weather this was apt to putrefy, and rise in large flakes, thereby promoting the decomposition of the supernatant water, and rendering it turbid.

Wherever these conditions have been observed, and the process has been carefully conducted, the results have been satisfactory, and no nuisance has been created; but, on the contrary, when the working of the process has been neglected, as at Tottenham since Mr. Higgs's time ; at Leicester on many occasions, and notably of late ; at Cheltenham ; at Blackburn ; and at Leamington before the A. B. C. process was adopted, the defæcation of the sewage has been very imperfect, and complaints have been justly raised against the nuisance occasioned by the neglect of those who have had the care of the work.

In concluding this part of the subject we may refer to the observations of Dr. Hoffmann and Mr. Witt in their "report of chemical investigations relating to the Metropolitan Main Drainage Question," wherein they state that "the treatment of sewage with lime appears to be one of the most promising of the many processes for obtaining

from sewage a deposit which, when dry, may be employed as manure;" and they give the following as the result of their experiment on 40 gallons of London sewage with 800 grains of lime (that is, with 20 grains of lime per gallon of sewage):—

Constituents per gallon.	Raw Sewage.	Effluent water.
	Grains.	Grains.
Matters in solution . . .	107·60	96·02
Organic matter . . .	52·36	40·34
Mineral ditto . . .	55·24	55·68
Matters in suspension . .	52·49	
Organic matter . . .	36·40	Traces.
Mineral ditto . . .	16·09	

So that, with 20 grains of lime, the whole of the suspended matters were removed from the sewage, and rather more than a fourth part of the dissolved organic matter; in fact, the total quantity of organic matter removed amounted to 54·55 per cent. of all that was present in the original sewage. With 12 grains of lime at Tottenham, we found the proportion to be 35 per cent., and at Leicester, 58 per cent.; whereas, according to Mr. Versmann, the average amount of organic matter removed from the sewage at Leicester, in the ordinary way of working is 38 per cent.

The composition and money value of the dry deposit from the sewage of different places, as determined by different investigators, will be found in the following table.

These values are calculated at the rate of £56 per ton for ammonia, £7 a ton for insoluble phosphate of lime, and £1 a ton for organic matter; and it is assumed that the Tottenham deposit contained 0·82 per cent. nitrogen, which is equal to 1 per cent. ammonia.

Constituents per cent.	Tottenham. (Higgs.)	Leicester. (Voelcker.)	Leicester. (Versemann.)	London. (Hofmann and Witt.)	Clifton Union. (Hofmann.)
Moisture	5·25	10·52	4·06	0 00	0·00
Organic Matter . . .	31·60	12·46	26·32	43·95	20·12
Phosphate of lime . .	8·64	2·27	2·32	6·35	3·08
Mineral matter . . .	54·51	74·75	67·30	49·70	76·80
Total	100·00	100 00	100·00	100·00	100 00
Nitrogen	—	0·60	0·56	1·55	0·62
= Ammonia	—	0·72	0·68	1·88	0·75
	s. d.	s. d.	s. d.	s. d.	s. d.
Money value per ton of dry substance	29 6	15 5	17 0	38 9	16 9

It is manifest, therefore, that the process for precipitat-

ing sewage by means of lime has been generally regarded by chemists as satisfactory in its results, when properly managed; for in addition to the authorities already quoted (Dr. Hofmann, Mr. Witt, Dr. Clark, Dr. Crace Calvert, Mr. Versemann, Dr. Frankland, Dr. Letheby, and Dr. Odling), we may add the following: Dr. Angus Smith, Mr. Aikin, Dr. Alfred S. Taylor, Dr. Normandy, and Dr. Miller. Dr. Angus Smith used lime for the defæcation of the foul water of the River Medlock at Manchester, and found it successful. Mr. Aikin and Dr. Alfred S. Taylor examined the process in 1851 for Mr. Wicksteed, and reported of it in these words:—"We can state of our knowledge, and from our own experiments, that by your process the nitrogenous organic matter, as well as the phosphoric acid, dissolved or undissolved, would go down and be retained in the solid deposit; while the water, after the precipitation is completed, will be discharged in a limpid state, and free from the offensive matter which it previously contained. We consider your process has, in fact, these advantages over every other plan which has been proposed—it provides for the immediate and rapid sewerage of a district at all periods; it prevents the contamination of a river, or other source of water supply, by removing all noxious animal and vegetable matters; it provides for a speedy deodorisation, separation, and drying of the solid and useful parts of the sewage; and lastly, it furnishes to the agriculturist a cheap and useful manure." In a trial at Hertford during the spring assizes of 1858, when an action was brought by Mr. Higgs against the Hitchen Local Board of Health for an infringement of his patent, Dr. Normandy and Professor Miller, who gave evidence on the subject, spoke in high terms of the value of the lime process, saying it was of public utility. The failure, therefore, of the procsss is evidently due to the carelessness and parsimony of those who have hitherto had the management of it.

PRECIPITATION OF
SEWAGE WITH THE SALTS OF ALUMINA AND IRON.

The salts of alumina and iron have been the subjects of numerous patents for the disinfection of night-soil and sewage. The preparations of alumina, for example, are mentioned in the patents of Siret (1843), Browne (1850), Stothert (1852), Pinel (1856), Manning (1853, 1854, and 1855), and others; and the compounds of iron are claimed in the patents of Deboissieu (1762), Briant (1824), Siret (1837), Barounet (1845), Dubois (1846), Brown (1847), Ellerman (1847), Browne (1850), Gilbee (1852), Dimsdale (1853), and others.

All these inventions rest on the well-known property of the recently precipitated oxides of iron and alumina, to combine with the organic matter contained in the solutions in which they are precipitated, and to form insoluble compounds therewith. In the case of alumina, its affinity for organic colouring matters is so great that it is not merely used as a mordant or fixing agent for such colours when applied to fabrics, but it is also employed to precipitate these matters from their solutions, and to produce the insoluble compounds called "lakes." Even when alumina

and oxide of iron are used in their denser condition, as they exist in common earth or loam, they have the power of absorbing and fixing soluble organic matters, as well as the compounds of ammonia and phosphoric acid. It is natural, therefore, that these substances should have been proposed for the purification of sewage.

The *salts of alumina* claim our first attention, because they are somewhat more effective as defæcating agents than those of iron; and the earliest practical suggestion for their use is in the patent of Mr. Stothert, dated the 17th of April, 1852. He therein recommends that fresh made caustic lime, sulphate of alumina, or sulphate of zinc, and a combination of animal and vegetable charcoal, obtained from sewage or night-soil, should be employed for the precipitation of the substantial parts of sewage water, so as to produce a valuable manure. This process was tried in the year 1857 by Dr. Hofmann and Mr. Witt, when they were experimenting on London sewage, and they found that it rapidly caused the flocculation and precipitation of it. Forty gallons of ordinary sewage were treated with five ounces of lime and ten ounces of the mixture of charcoal and sulphate of alumina. The lime, which was first added to the sewage, produced considerable aggregation of the suspended matters; but the aluminous preparation caused a marked increase in the flocculation and separation of these matters, forming them into a dense precipitate which rapidly subsided. The effect of this treatment of the sewage was as follows:—

Constituents per gallon.	Raw sewage	Effluent Water.
	Grains.	Grains.
Dissolved matters . . .	107·60	87·73
Organic matter . . .	52·36	37·56
Mineral ditto . . .	55·24	50·17
Oxygen required for oxydation	—	—
Matters in suspension . .	52·49	0·00
Organic matter . . .	36·40	0·00
Mineral ditto . . .	16·09	0·00

In this way the whole of the suspended matters were removed, together with 19·87 grains of the dissolved matters, and of this 14·8 were organic, so that nearly 58 per cent. of the total amount of organic matter in the sewage was thus removed. The precipitate when dried contained 1·21 per cent. of nitrogen (= 1·44 ammonia), 3·97 phosphoric acid (= 8·6 bone earth), and 35·97 organic matter, and it was worth two guineas per ton. According to Mr. Stothert, a ton of the materials, costing 30s., will make two tons of manure.

In the year 1853, Mr. James Alexander Manning obtained a patent for defæcating and separating certain matters from sewage by means of animal charcoal, alum, and carbonate of soda and gypsum, the precipitate being mixed with certain waste products, rich in phosphates, so as to form manure; but as the use of alum was found to be expensive, he improved the patent in the following year (1854) by employing a waste product called "soft sludge," from alum works. This is the deposit which forms during the first boiling down of the rough liquors obtained from alum shales in the manufacture of alum, and it consists of basic and other sulphates of iron and alumina. Later still, in 1855, he again improved the patent and cheapened the production of the alum compound by the application and use of alum slate, alum shale, alum schist, alum stone, and alum ore, and other aluminous minerals and earths, as precipitating and clarifying agents for cleansing sewerage matters. The method which he recommended for the preparation of these shales, &c., was much the same as that used in the early part of the ordinary process for making alum whereby the material called "soft sludge" is obtained; and in this manner an aluminous compound is easily obtained at a price, according to Mr. Manning, of about five shillings a ton. He also recommends in each of his patents that powdered caustic lime and animal charcoal should be used with the aluminous compound: his directions are that the soft sludge, or other aluminous

preparation, is first to be added to the sewage, and then, while it is being agitated, the powdered caustic or unslacked lime and animal charcoal are to be thrown in; after which it is to be allowed to subside in the precipitating tanks. The process was carefully tried in Edinburgh and a few other Scotch towns, and it was reported very favourably of by the late Professor Penny, of Glasgow, who found that it defæcated sewage in a very satisfactory manner, and gave a product which contained 2·22 per cent. of ammonia, 2·05 of phosphate of lime, and 43·72 of organic matter. This product, according to Dr. Hofmann and Mr. Witt, is worth £1 16s. 5½d. per ton. Another sample of the precipitate, from the sewage of Pinckston Burn, analysed by Dr. Penny in 1854, contained 31·74 per cent. of organic matter (with 0·728 nitrogen, = 0·884 ammonia), and 13·57 per cent. of phosphate of lime. According to Dr. Penny this was worth 35s. per ton.

More recently still a like process has been patented by Mr. Lenk for the defæcation of sewage by means of a solution of crude sulphate of alumina, called "alum cake." We examined a sample of Mr. Lenk's solution in the year 1865, and found that it contained about 12 per cent. of alumina. A gallon of ordinary London sewage required 24 5 grains, by weight, of the solution to defæcate it, and in twenty minutes the flocculent precipitate had completely subsided, leaving a perfectly clear and almost inodorous supernatant fluid. In the year 1868 the process was tried for more than a week on the sewage of Tottenham, and the results were quite satisfactory to the local authorities, for they say that "a cask of water taken from the tank became, after settling, perfectly clear and free from all smell, two gold fish living in it for some weeks." From three to three and a-half cwt. of the chemicals were used per day for about 700,000 gallons of sewage, or one ton per week, at a cost of £6 10s. The process was examined by Dr. Voelcker, who analysed the several products, and reported that "Lenk's Deodorising Liquid certainly effects

a ready precipitation of suspended sewage matters, and at the same time removes a very large proportion of obnoxious soluble refuse matters. The sample of deodorised Tottenham sewage, examined by me, certainly was very satisfactorily disinfected. Sewage, after efficient treatment by Lenk's process, in my judgment, may be poured into a water-course without causing a nuisance like ordinary sewage." According to Dr. Voelcker's analysis, the following was the composition of the raw sewage and the defæcated sewage water :—

Constituents per gallon.	Raw Sewage.	Effluent Water.
	Grains.	Grains.
Dissolved matters	91·10	63·39
Chloride of sodium . .	14·46	14·21
Ammonia	9·76	4·23
Organic matter . . .	42·30	9·70
Phosphoric acid . . .	3·77	trace
Matters in suspension . .	367·70	3·01
Organic matter . . .	225·60	0·77
Mineral ditto . . .	142·10	2·24
Total ammonia obtainable .	24·237	5·103

From which it appears that the process removed almost the whole of the suspended matters, and 27·71 grains of the dissolved matters, 32·6 grains of which were organic. The precipitate when dry contained 1·86 per cent. of nitrogen (= 2·26 ammonia), 4·91 phosphoric acid (= 10·71 of bone earth, and 42·26 of organic matter. "In a perfectly dry state," according to Dr. Voelcker, "the deposit would be worth to the farmer about £2 2s. a ton. In such a perfectly dry state, however, it is not possible to obtain it on a large scale. Sufficiently dry to become powdery, the sewage deposit would probably retain from

one-fourth to one-third its weight of water, and in that condition, the sample would be worth from 25s. to 30s. a ton as manure." Looking, therefore, at the profit of the results, it would seem that, if all the sewage of Tottenham produced, as in the present instance, at least 392·4 grains of dry deposit per gallon of sewage, the 4,900,000 gallons per week, must furnish nearly 123 tons of dry deposit, which, with one-third of its weight of water, to form a commercial product, would weigh about 164 tons—worth according to Dr. Voelcker, 25s. a ton. So that for an outlay of £6 10s. per week, for a ton of Lenk's chemicals, there would be realised a product werth £205. Even supposing that the suspended matter of the sewage amounted to only 38·2 grains per gallon, which is the average of London sewage, the return would have been sufficiently large to have deserved the attention of the Tottenham Local Board of Health, seeing that they were not only the custodians of the public health, but were also under an injunction not to pollute the river Lea with their undefæcated sewage. All the attention, however, which it received from them was, a memorandum to the effect that "Lenk's process was tried for more than a week at the Tottenham works, with very fair results." They did not even go to the trouble of ascertaining what was the real effect of the process on the effluent water, or what was the nature of the deposit obtained. This, however, is only one example of the many ways in which the carelessness and parsimony of our local sanitary boards are constantly bringing the sewage question into the region of difficulty and doubt; and, in this case, if it had not been for the investigations of Dr. Voelcker, it would most probably have been said that the process of Lenk had been tried at Tottenham and had failed.

Other processes have been proposed for the defœcation of sewage by the aid of an impure sulphate of alumina and iron. made from sulphuric acid and common clay, but, as these will be best examined after the consideration of the

several processes for defœcating sewage by means of the sales of iron, we shall defer them for the present.

"The *salts of iron* have been used for more than a hundred years as disinfectants of night soil and foul water, and they have, as already stated, been the subjects of numerous patents. The most important of these were the patents of E. Brown and C. F. Ellerman, both of which were granted in the year 1847. Brown's invention dates from the month of February of that year, and it professes to be a means of "neutralising the odious and noxious gases emanating from fecal substances, or as it is sometimes termed, the 'disinfecting' of such substances, whereby they may be preserved, in order to their being manufactured into carbonic compounds applicable as manures, without injury to the public health, or to individuals engaged in such collection and manufacture;" and among the substances employed for this purpose were the sulphates and chlorides of iron. In the month of October of the same year Mr. Ellerman obtained a patent for "certain processes or methods of rendering feculent, excremental, and other matters inodorous, and of disinfecting, and also of retarding, the putrefaction of animal and vegetable substances." The chemical preparations which he used were the crude chlorides, and pyrolignates or acetates of iron. Mr. Edward Brown's invention does not appear to have commanded much attention, but Mr. Ellerman's was brought prominently into notice, and was frequently made the subject of public inquiry. We examined his liquid shortly after the date of the patent, and found that it was a strong solution of perchloride and pyrolignate of iron, having a specific gravity from 1336 to 1443, and containing from 24 to 43 per cent. of these ferruginous salts. The retail price of the preparation was eighteenpence a quart, but Mr. Ellerman offered to sell it wholesale for ninepence a gallon. Directly after the patent was obtained, the deodorising effects of the liquid were tried by Dr. Sutherland and the late Dr. Duncan, of

Liverpool, and in the following year (1848) its action was still further investigated by the late Dr. Ure and Mr. Scanlan, all of whom reported most favourably of its disinfecting power, when compared with the well-known deodorising solutions of Sir William Burnett, Labarraque, and Ledoyen. Our own experiments, however, at that time did not furnish equally satisfactory results; for we found that 100 grains of Sir Wm. Burnett's solution of chloride of zinc, of specific gravity 1594, were quite as effective in deodorising sewage as 470 grains of Ellerman's solution, of a gravity of 1443. Mr. Haywood, also, the engineer of the City Commissioners of Sewers, inquired into the subject, and reported that when Ellerman's solution was used in the proportion of three gallons to a cubic yard of night-soil, it was not so perfect in its deodorising power as five pints of a solution of chloride of zinc. In the same year (1848) Mr. Hodgson reported to the Metropolitan Sewers Commission, that when the solutions were used in sufficient quantity to remove the sulphuretted hydrogen and ammonia from a cubic yard of night-soil, it required eleven and a-half quarts of Ellerman's liquid to do the work of one quart of Sir Wm. Burnett's. More recently, however, in 1859, the deodorising power of a strong solution of perchloride of iron, called Dale's liquid, was thoroughly investigated by Drs. Hofmann and Frankland, and subsequently by the late Dr. Miller, for the Metropolitan Board of Works, who were anxious to prevent as far as possible the putrefactive decomposition of the sewage in the River Thames during the hot summers of 1857 and 1860. The solution which they employed had a specific gravity of 1450, and its price was sixpence per gallon. This was compared with the effects of chloride of lime, costing £12 a ton, and ordinary caustic lime, at sixpence a bushel. When used in quantities of equal value they found that the perchloride of iron had a marked superiority over the two other disinfectants, and that chloride of lime was more powerful than quicklime; in

fact, they ascertained that an immediate deodorisation of 7,500 gallons of sewage was effected by each of the three agents when used in the proportions of half a gallon of perchloride of iron, three pounds of chloride of lime, and one bushel of lime. The quantity, therefore, required to deodorise a million gallons of sewage, and the cost thereof, in each case, were as follows :—

	£	s.	d.
86 gallons of perchloride of iron .	1	13	3
400 lbs. of chloride of lime . .	2	2	10½
132½ bushels of lime	3	6	6

But the permanency of the deodorising effect of the several substances was very different in the three cases; for, they say, that after two days the sewage disinfected by lime became slightly tainted, whilst that deodorised by chloride of lime and perchloride of iron remained perfectly odourless. At the end of three days the limed sewage had become decidedly offensive, whilst the other two specimens still remained free from smell. After four days the odour of the limed sewage had become worse, but that treated with chloride of lime likewise began to exhibit an offensive character, whilst the sewage to which perchloride of iron had been added remained perfectly inodorous. Even after the lapse of nine days the condition of the latter had not changed. The chief cause of the decomposition of the deodorised sewage was no doubt the organic matter contained in the precipitate, and therefore they recommended that the suspended matters should be removed from the defæcated sewage as soon as possible. But as this was not practicable in the case of the London sewage, the proposition of Dr. Hofmann and Dr. Frankland to add perchloride of iron to it without separating the suspended matters, was objected to by Dr. Letheby and Dr. Odling in their reports to their respective local sanitary boards. Dr. Odling, indeed, was of opinion that the action of the perchloride under these circumstances would be much the same as

that of lime, though perhaps a little more permanent, for it would produce a black sludge of precipitated mud which would be scarcely less liable to putrefactive decomposition, and would be more objectionable to the eye, than the undefæcated sewage ; whereas the clarified sewage, deprived of this mud, might be safely discharged into the river. Dr. Letheby, in his report to the Commissioners of Sewers for the City, expressed himself to nearly the same effect, saying that the mere addition of a precipitant, without the separation of the fæculent matters so precipitated, would be worse than useless. He also attached importance to the presence of a large quantity of arsenic in Dale's solution, which, by combining with the iron, would be found in the precipitate. According to his analysis of a sample of the perchloride furnished to him by Mr. Dale, as that proposed to be used by the Metropolitan Board, there was enough arsenic in it to yield as much as a hundredweight and a-half of this poison to the Thames daily, if used in the quantity proposed by the chemical referees ; and all this would be retained by the precipitated mud, giving a proportion of one part of arsenic to three thousand parts of the precipitate. This, however, was thought lightly of by the referees, who said, in their reply to his report, that it was their " deliberate opinion that even were the perchloride of iron to contain ten times the maximum quantity of arsenic observed by Dr. Letheby, its application for the purposes contemplated in our report could not afford grounds for the slightest apprehension of danger ;" but in answer to this it was very properly asked,—What would have been the conclusions of these gentlemen if in their professional capacity as witnesses for a prosecution, they had ascertained that a manufacturer on the banks of the Thames was daily discharging into the river a quantity of refuse containing as much as a hundredweight and a-half of arsenic ? and what also would have been the undoubted result of a legal prosecution, if the Conservators of the river had, in the exercise of their duty, applied for an in-

junction to prohibit such a practice? It is fortunate fo the public that the question has been re-examined by Dr. Frankland, in his capacity as one of the Royal Commissioners appointed to inquire into the pollution of rivers; for he now suggests that, "any liquid which, in 100,000 parts by weight, contains, *whether in solution or suspension*, in chemical combination or otherwise, more than 0·05 part by weight of metallic arsenic, shall be deemed polluting, and shall not be admissible into any stream." In point of fact, it is manifestly of the greatest importance that the precipitate produced by the chemical action of perchloride of iron in sewage, should be carefully removed from the defæcated water, and not allowed to pass into the stream.

In the years 1859 and 1860, attempts were made to deodorise the sewage of Croydon by means of perchloride of iron. It was used in the proportion of from 120 to 140 gallons of Dale's liquid, to from 800,000 to 1,400,000 gallons of sewage; that is in rather more than double the quantity recommended for the Metropolitan sewage; but as the separation of the suspended matter was not properly effected, the results, as might have been expected, were not satisfactory; for the black precipitate of sulphide of iron contained in the effluent water, gave it a disgusting appearance, and marked in a very objectionable manner the exact course of the undefæcated sewage discharged into the river; besides which the precipitate adhered to the herbage upon the banks of the stream, aud formed an offensive slimy deposit. As in the case of lime, and every other precipitating agent, it is evidently essential to the success of the process that all suspended matters should be carefully removed from the effluent water before it is discharged into a running stream; and this appears to be effectually accomplished by means of subsidence and filtration at Ealing, where the sewage is treated with lime and a cheap salt of iron made on the premises by a process recommended by Professor Way. The lime, in a slaked

condition, is added to the sewage as it enters the works and is passing onwards to the subsiding tanks—where the precipitate produced by the lime and the other suspended matters of the sewage subside; and at the last subdivision of the tanks, a solution of iron salt is allowed to run into the defæcated sewage water in a graduated manner—advantage being taken of a slight fall to move a little water wheel, which assists in effecting the mixture of the iron salt with the sewage water. It then flows upwards through two filter beds, and is discharged from the works in a nearly bright and inoffensive condition. Professor Way has reported on the process, after having made more than thirty visits to the works since the month of July, 1869—two-thirds of which were during the hot and dry months of last summer; and although the state of the weather necessarily affected the process, yet he says:—"Since the system has been in good working order, I have considered the result to be very satisfactory. The effluent water, though not absolutely bright, has only a faint milkiness, which a more liberal use of chemicals would entirely remove. It is free from smell, and samples that have been kept for weeks have only in rare instances become offensive." On a former occasion, in 1868, when merely subsidence and filtration were practised at the works, the defæcation of the sewage appears to have been very effective; for a sample of the effluent water, analysed by Dr. Letheby, for the Conservators of the river Thames, was found to be perfectly transparent, and free from offensive odour. It contained only fifty-six grains of solid matter per imperial gallon, all of which was in solution, and it consisted of calcareous salts, chloride of sodium, and alkaline nitrates, with a very little organic matter and ammonia. The liquid, in fact, was so absolutely inoffensive, that, on the certificate of Dr. Letheby, the Board of Conservators permitted it to flow into the Thames; and we are not aware that any offence has been created thereby. Professor Way, in speaking of these filters, says in

his recent report—"They are, in my opinion, of very great importance in carrying out any process of purification of the sewage before it is discharged into the Thames. Without them it would be impossible, by the best precipitants known, to clarify the sewage in the tank; for no matter how perfect the system of precipitation may be, there is always some portion of flocculent matter which will not settle, and which can only be removed by filtration. These filter beds are an excellent feature of the Ealing Sewage Works;" and now that the process of precipitation is superadded to that of filtration, he considers the works to be among the most perfect, if not the most perfect, of their kind in the country. The two depositing tanks, which, like the filters, are in duplicate, are each sixty-four feet long, ten feet wide, and ten feet deep. They are divided into five compartments by cross planks, having small openings at the top for the passage of the sewage, and their total capacity is about 12,000 cubic feet. The first filter is composed of gravel, thirty feet long, ten feet wide, and two feet thick, and the second filter is of fine sand, sixty feet long, ten feet wide, and two feet thick. The population of Ealing is about 8,500; and the quantity of sewage received at the works amounts to about 400,000 gallons a day, or nearly 3,000,000 gallons a week. In summer time, when the chemicals are most freely used, the weekly proportion of lime is one and a-half square yards, or about 20 cwt. (costing 20s.), and the amount of the iron preparation is 15 cwt. (costing 60s.); but in winter time less would be used. In fact, according to the estimate of the borough surveyor, Mr. Charles Jones, the average annual cost of the works for chemicals, labour, &c., would be about £325, from which there is to be deducted the sum paid by farmers for the manure. This, at present, is about £60 a-year; but if the precipitate were mixed with town refuse, as at Northampton, it would realise much more.

Sulphate of iron, in the form of weathered shales or

lignites, and copperas has also been used, either alone or in conjunction with other things, for the deodorization of sewage and nightsoil. The patent of Mr. Richard Dover, for example (1851), claims the use of acids with iron filings or oxide of iron and protosulphate of iron—the defæcated sewage being filtered through charcoal, peat, &c. Later still, in 1853, Mr. Herapath's process was a combination of one part of sulphate of iron and four parts of burnt magnesian limestone—the mixture being intended to precipitate the phosphoric acid of the sewage in combination with the magnesia, as well as the sedimentary matters. The process was tried for some time at the sewage works of St. Thomas, near Exeter, when it was found that a ton of the materials produced two tons of dry manure, at a cost of 17s. a ton ; but the process was not remunerative, and was therefore abandoned. More recently, a preparation of dry copperas, called Mudie's disinfectant, has been used for the deodorization of drains, stable manure, and nightsoil. It freely absorbs the ammonia and sulphuretted hydrogen of such matters, and renders them inoffensive. It has, therefore, been extensively employed in France, for the purification of slaughter houses, ditches, drains, &c. Very recently, it has been examined by Dr. Letheby and by Mr. Crookes, who say that it is well fitted for this purpose, although it is hardly suited for the defæcation of sewage. Lastly—the process of MM. Jules Houzeau and Eugène Devedeix, of Paris, which was patented in 1866, consists in the use of lignites, containing sulphate of iron, or of sulphate of iron itself with lime and coal dust. This process has been extensively tried at Bradford by Mr. Holden, and hence it is generally called Holden's process. About 130,000 gallons of Bradford sewage are daily treated with the proper proportion of sulphate of iron, and then with caustic lime, previously slaked, and coal dust. The mixture passes into a series of subsiding tanks, where the time of flow is about twenty minutes ; and thus the precipitate falls and

leaves a clear, supernatant liquid, which is quite inodorous. All the sedimentary matter of the sewage is thus got rid of, as well as about half of the dissolved organic matter. The precipitate when dried in the air contains about forty-three per cent. of organic matter, and rather less than one per cent. of phosphate of lime. The organic matter is not very rich in nitrogen, and, therefore, the manure is not of much value.

Chloride of iron and lime were formerly employed as precipitating agents for the sewage of Northampton, and when the process was conducted in a proper manner the results were highly satisfactory. At the time of our first visit to the place, in 1862, the sewage was only about 400,000 gallons a day, the town being but partially drained, and it flowed by gravitation to the works, which are upon the banks of the River Nene, about half-a-mile from the town. As it entered the works it received a dose of lime and chloride of iron from two small tanks, which were charged in the following manner :—Each tank contained its own material in a solid form, and it was supplied with water from a small tap that was constantly running. The solution and suspension of the materials in the water were effected by means of revolving stirrers moved by a boy, and the overflowing water carried the solutions into a common pipe, which discharged them into the sewage. The solutions, therefore, became mixed, and were decomposed before they reached the sewage. There was no contrivance for agitating the sewage after the chemicals had been added to it, but it flowed onwards to the first subsiding tank, which was 40 feet long and 30 feet wide, and from this it passed through the openings of a cross-wall into a second subsiding tank 60 feet long and 30 feet wide, from which it escaped by a weir a little under the surface of the liquid, into an outfall channel about a mile long, which conveyed it to the River Nene. The subsiding tanks had an average depth of five feet, but the bottoms of them sloped from the sides to the centre, where there was a gutter with an Archimedian screw for driving for-

ward the precipitate to a central well, from which it was lifted by an endless chain of buckets. Each set of tanks worked a fortnight before the sludge was removed, and it was conveyed into properly prepared pits, where it was consolidated by mixing it with the town refuse. In this manner about 7,000 tons of manure were annually produced, and sold for 1s. 9d. per load. The quantity of chemicals daily used were from 60 to 70 lbs. of solid chloride of iron, and from 10 to 12 bushels of lime. Dr. Letheby investigated the process for the Town Commissioners, and we gather from his published report that he recommended an entirely different method of working. "The chloride of iron," he said, "should be dissolved in the water and allowed to run by a graduated stream into the sewage before it reaches the lime. A contrivance should also be used for effecting a perfect mixture of the iron solution with the sewage. This having been accomplished, the sewage should then receive its dose of lime-liquor, and be again well agitated, so as to be thoroughly mixed. In this manner a heavy clotty precipitate will be produced which will rapidly fall in the subsiding tanks, and leave the supernatant liquor perfectly clear and inoffensive. The proportions of chloride of iron and lime should be about 4·5 grains of the former, and from 14 to 15 grains of the latter per gallon of sewage, and the quantities should be so regulated as that the supernatant liquor at the outfall shall be clear, colourless, and but faintly alkaline." This improvement of the process was adopted by the Commissioners, and after it had been in operation for about a year the engineer of the works reported that the results were satisfactory, and that a manure was produced at a cost of 1s. a ton, which was readily saleable at 4s., and which by chemical analysis was valued at 15s.; for, according to Mr. Harris, the analytical chemist of Northampton, it contained 12·1 per cent. of organic matter (with 0·916 nitrogen = 1·112 ammonia), and 0·454 of phosphate of lime. At a later date, in consequence of the difficulty of procuring chloride of iron, the

salt was manufactured on the works from native oxide of iron, at a cost of £6 a ton ; and it contained about 9,400 grains of the mixed chlorides of iron per gallon. It was used in the proportion of six gallons to a million gallons of sewage, to which about 12 bushels of lime had been previously added. These are in the proportion of only 0·006 of a grain of chloride of iron, and 5·88 grains of lime per gallon, quantities which are manifestly insufficient for the perfect defæcation of the sewage. Nevertheless, at the time the works were visited by the Royal Rivers' Pollution Commissioners, they reported that "the effluent sewage, after a flow of a mile and a-half through a culvert, in which it becomes mixed with about one-sixth of its volume of spring water, is discharged into the River *Nen*, in a nearly clear and apparently innocuous condition. We examined the stream for about one-third of a mile below the outfall, and could perceive no sewer fungus or other sign of sewage pollution." In their opinion, however, the decomposition was merely delayed, as the effluent sewage water contained about 1·245 grains of organic nitrogen. At a subsequent visit to the works, in the month of April of the present year, we found that the sewage was treated in the following manner :—The present population of Northampton is about 40,000, and the sewage amounts to about a million gallons a-day. Instead of being precipitated with chloride of iron and lime it is defæcated with crude sulphate of alumina and iron made from a ferruginous clay and sulphuric acid. Two tons of clay are mixed with three cwt. of crude sulphuric acid, of chamber strength. The mixture is effected in wooden troughs, and as there are six of these troughs, one being almost entirely used out daily, the materials stand in chemical contact for about a week. It is then fit for use, and is diluted with water by placing it in another trough, set upon an incline, and having two cross breaks for checking the flow of the water, which runs into it at the rate of five or six gallons a minute. The dilution is effected by hand labour assisted by a shovel, and the crude chemicals

are carried forward into the sewage as it enters the works. There is no contrivance for agitating the sewage before it enters the subsiding tanks, and hence there is but an imperfect flocculation of the suspended matters; besides which, the acid of the chemicals acts upon the carbonates of the sewage and produces a notable effervescence, thereby causing the suspended matters to rise and form a thick scum. This accumulates to a large extent in the first subsiding tank, and is kept back by cross walls with floating planks. From this tank it passes over a weir into the second subsiding tank, already described, and which has alternating cross walls that reach nearly to the end. By this means the sewage is made to take a circuitous route before it passes over the weir into the covered outfall channel, which carries it for rather more than a mile, and then discharges it into the river. At the time of our visit about 15 cwt. of the sulphated ferruginous compound were used to the million gallons of sewage per day, and it was evident that it eventually defæcated the sewage very effectually, for the effluent water was remarkably clear and inoffensive, and gave the following chemical results :—

Constituents per gallon.	Raw sewage.	Effluent water from 1st Tank.	Effluent water from Outfall.
	Grains.	Grains.	Grains.
Solid matter in solution -	73·60	70·16	70·65
Chloride of sodium -	18·39	17·78	17·32
Organic matter - -	18·16	15·62	12·81
Ammonia - - -	4·980	4·190	3·247
Ditto organic* - -	0·313	0·233	0·200
Oxygen required to oxydise - -	2·265	1·980	1·243
Matter in suspension -	13·85	4·97	1·74
Organic matter - -	8·48	2·91	1·11
Mineral ditto - -	5·37	2·06	0·63

These samples were taken continuously over a period of twenty-four hours ; and the examination of the river below the outfall showed that the results must have been generally very effective, for the bed of the stream was quite free from sewage matters, the aquatic vegetation was clean and healthy, and the fish were abundant. It is possible, however, that occasionally, as the process is entirely managed by hand labour, the sewage may not be thoroughly disinfected, and therefore it was considered advisable to improve the works by a more perfect system of machinery. At present, about 400 tons of solid matter are removed from the subsiding tanks every week, and these, with about 48 tons of sifted ashes, and 20 tons of the burnt refuse called soft core, are made into a compost which sells for 3s. a ton, thereby realising about £600 a-year.

At Stroud, in Gloucestershire, the sewage is treated with crude sulphate of alumina and iron obtained by adding 120 lbs. of sulphuric acid to 6 cwt. of powdered clay, and allowing the mixture to stand for several days. The process is known as Dr. Bird's, and the sewage works are managed by a private company. The population of the place is about 37,000, but only from 150,000 to 200,000 gallons of sewage are dealt with by the Company daily, and these are mixed with the above-mentioned quantity of sulphated clay, the proportion being from 28 to 37 grains per gallon, and this is regulated in its delivery by two small water-wheels, which are turned by the sewage itself. The material falls into the sewage immediately before it enters the settling tanks, and the effluent water is filtered through three coke filters before it is discharged from the works. In this manner the whole of the suspended matters are removed from the sewage as well as a large portion of the dissolved organic matter. The precipitate is dried and then mixed with sulphate of ammonia and phosphate of lime, by which means a valuable manure is obtained.

Dr. Anderson, of Coventry, has lately recommended crude sulphate of alumina with lime for the precipitation of the sewage of that city. He produces the sulphate by adding one part of common sulphuric acid to two parts of ordinary clay, and then mixing it with its own bulk of water. The materials are allowed to stand in a warm place until they appear white upon the surface, which is the sign of proper chemical combination. They are then used in the proportion of one pound of the sulphated mixture to every one hundred gallons of sewage, and, after being well agitated, they are precipitated with a quarter of a pound of lime, previously slaked and diluted with water. Instead of working the depositing tanks in the usual manner, by a constant flow of sewage, he recommends that the tanks should be sufficiently large to hold a day's sewage, and that when the precipitating agents have been added, and the sewage has been well stirred, it should remain at rest for twenty-four hours, in order that the precipitate may entirely subside. He then draws off the clear supernatant water, and removes the precipitate. In our own experiments with the material, we found that it defæcated the sewage in a very satisfactory manner, and yielded a good precipitate. The process has been recently tried on a large scale at Coventry by Dr. Anderson, who has made use of one of the tanks at the sewage works of the town. The tank contained 100,000 gallons of sewage on each occasion, and these were treated with nine and a-half hundredweight of the sulphated material, which, after thorough agitation, was precipitated with one and three-quarters of a hundredweight of lime, previously slaked. The mixture was allowed to stand for twenty-four hours, when it yielded a clear supernatant liquid, which was analysed for the corporation by Dr. Odling. He found that a large portion of the dissolved organic matter, especially that which is rich in nitrogen was removed. The following, in fact, were the chief constituents of the raw sewage and the effluent water:—

Constituents per gallon.	Raw sewage.	Effluent water.
	Grains.	Grains.
Solid matter in solution . .	42·77	56·28
Chloride of sodium . .	7·58	5·95
Organic matter . . .	8·33	6·30
Ammonia	0·77	0·84
Ditto organic . . .	4·00	0·77
Matters in suspension . .	89·74	1·61
Organic matter . . .	51·66	0·91
Mineral ditto . . .	38·08	0·70

In another experiment the effluent water was analysed by Dr. Voelcker, who found that it contained 62·51 grains of soluble matter per gallon, and of this quantity 9·31 were combustible (organic, &c.) Besides which, it contained 1·74 grains of suspended matter, 0·3 of which was organic matter. Dr. Voelcker says of it that, "It is so thoroughly deprived of obnoxious impurities, that, in my opinion, it may be discharged into a running stream or water course without risk of creating a nuisance."

Dr. Anderson calculates, from his experiments on the night and day sewage of Coventry, that about twenty-two tons of dry manure will be obtained from every million gallons of sewage. The manure has been carefully analysed by both Dr. Voelcker and Dr. Odling, and the following was its composition on three occasions :—

Constituents per cent.	Dr. Voelcker.		Dr. Odling.
Moisture	12·01	15·70	20·16
Organic matter . .	26·89	31·86	22·98
Bone phosphate . .	2·60	2·55	2·20
Other mineral salts . .	6·61	10·33	16·47
Siliceous matter and clay .	51·89	39·56	38·19
Total . . .	100·00	100·00	100·00
Ammonia from Organic matter . .	1·39	1·22	1·44

According to Dr. Voelcker, the two samples have practically the same commercial value, and "will probably find a steady sale at about 30s. a ton." Dr. Anderson has gone very fully into the subject of cost in working his process, and he says that the total expense of producing a ton of manure from the sewage is eleven shillings—7s. 6d. being for the chemicals, and 3s. 6d. for labour, &c.; and for the sewage of Coventry, which amounts to about 1,500,000 gallons a day, the sum required for the erection of works would be about £7,000.

THE A B C PROCESS.

The A B C process of Messrs. W. C. and R. G. Sillar, and G. W. Wigner, which was patented in the summer of 1868, consists mainly in the use of alum, blood, and clay for the defæcation of sewage, the other agents being the compounds of manganese and of magnesia, chloride of sodium, and animal or vegetable charcoal. They claim, in fact, "first, the deodorising and purifying sewage by means of these chemical substances, and the so obtaining a sediment which may be used as manure; second, the deodorising and purifying sewage by means of the mud already precipitated from sewage, as above described; and, thirdly, the addition of an acid to the mud in order to retain ammonia, and fit it for use as a manure." The proportions of the ingredients which they recommended for ordinary sewage were—"alum, 600 parts; clay, 1,900 parts; magnesia, 5 parts; manganate of potash, 10 parts; animal charcoal, 15 parts; vegetable charcoal, 20 parts; and magnesian lime-stone, 2 parts. These substances are mixed together and added to the sewage to be purified until a further addition produces no further precipitate. The quantity required will be about four pounds of the mixture to one thousand gallons of sewage. In many cases it is preferable to mix the above compound with a small quantity of water, and add it in a liquid state to the sewage. The sewage must then be thoroughly mixed with the compound, and allowed to flow into settling tanks. The greater part of the organic and other impurities will be immediately separated in the form of large flakes, which rapidly fall to the bottom, leaving the supernatant water clear and inodorous, or nearly so. The water may then be allowed to flow away into a river, or be disposed of in any other way, and the sediment or mud allowed to accumulate at the bottom of the tank. In some cases it is preferable to add the compound of manganese to the water after the sediment produced by

the other ingredients has been allowed to subside. The sediment will be found to possess the power of precipitating a further quantity of sewage; it must, therefore, be pumped or otherwise taken from the tank and mixed with fresh sewage, the sediment being allowed to subside in the same way as before. The sediment may be used five or six times over in this way. When the sediment no longer possesses the power of precipitating the impurities in the sewage it must be removed from the tank and allowed to dry; when partially dry, a small quantity of acid—by preference sulphuric acid—may be mixed with it, which will retain all the ammonia in a soluble form. When dried, the sediment will be a valuable manure." Of the above-named substances the patentees say that the manganese compound, the burnt clay, chloride of sodium and magnesian lime-stone may be omitted, and the proportions of the others may be varied according to circumstances. In the following year (1870) Mr. Wigner obtained a patent for certain improvements in the working machinery of the process, as for the use of a catch-pit with a mud channel and well for collecting the grosser parts of the sewage before its treatment with chemicals, and second, for improved precipitating apparatus, whereby the sediment was more easily collected and removed from the tanks, and, thirdly, for improvements in the construction of filters, for filtering the defæcated sewage water. These patents are now being worked at Leamington, Hastings, and elsewhere, by a company called "The Native Guano Company, Limited." At Leamington the works have been in operation for some time, with a manifest improvement of the river, the local authorities being under an injunction not to pollute it with sewage. The works are on the banks of the Leam, about half-a-mile from the town, and close to a public promenade. The population of Leamington is about 20,000, and the sewage amounts to about 600,000 gallons a day in dry weather, the maximum flow being about 35,000 gallons an hour. When it reaches the works it enters a circular tank, eight feet in

diameter and six feet deep, where it is stirred by machinery, and thus mixed with the A B C materials, which are discharged into the tank from a chain of buckets at the rate of about two and a-half gallons per minute, or one part of the liquid materials to 100 of sewage. The sewage then passes into a pair of settling tanks, there being three sets of them for alternate working. Each tank is 32 feet long, 15 feet wide, and 6 feet deep, with a transverse wall a little below the surface of the sewage. The capacity of the tanks is not sufficient for the thorough defæcation of the sewage, nor is it sufficient for intermittent settling, and hence the effluent water is generally a little turbid, as it flows from the tanks over a shallow weir into the outfall channel which conveys it to the river. This channel winds upon itself for a distance of about 850 feet. It is 10 feet wide and 4 feet deep, and the last third of it was at that time converted into a filter of sand and animal charcoal. The superficial area of the filter was about 3,000 square feet, and we were informed that it worked for about three months, when it became foul and was removed. Each of the settling tanks is kept in action for a week, and then the sewage is diverted into another tank, and the sedimentary mud is removed, and converted into a stiff paste by means of centrifugal machines, which revolve at the rate of from 1,500 to 1,600 times a minute. The paste is still further dried by exposing it to the air for two or three days, after which it is sprinkled with dilute sulphuric acid, composed of one part of acid to six of water, the acid being used in the proportion of about one per cent. of the manure. After this it stands in a heap for about a fortnight, during which time it heats considerably, and forms a rotten compost, which is still further dried, and then riddled and sold for manure. We have visited the works on several occasions, and have noticed that the proportions of the precipitating agents have been varied according to the condition of the sewage. Eight sets of samples have been submitted by us to chemical examination, and the following are the results :—

Date, &c.		Dissolved matters per gallon.						Suspended ditto.	
		Total.	Chloride sodium.	Organic matter.	Ammonia.		Oxygen required.	Total.	Organic.
					Present.	Organic.			
		Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
Dec. 11, 1869	Raw sewage .	66·13	11·04	14·43	2·543	0·220	1·830	113·60	39·92
	Effluent water .	67·27	9·68	11·27	1·892	0·109	0·951	7·64	2·86
	Ditto filtered .	60·97	7·21	7·50	0·954	0·093	0·488	3·08	1·12
Jan. 29, 1870	Raw sewage .	67·81	14·64	11·09	3·769	0·200	1·804	43·44	14·72
	Effluent water .	51·33	6·01	7·61	0·315	0·060	0·406	1·04	0·30
April 20	Raw sewage .	94·10	18·76	19·25	3 200	0·352	2·400	50·14	29·06
	Effluent water .	72·27	12·52	13·70	3·840	0·200	1·600	2·26	1·12
July 14	Effluent water .	72·33	9·20	6·15	2·520	0·114	0·252	0·60	0·12
Sept. 20	Raw sewage .	86·67	16·52	17·30	4·125	0·711	3·512	34 64	22·12
	Effluent water .	74·93	11·57	13·10	3·467	0·150	1·023	1·54	0·52
Sept. 21	Raw sewage .	81·10	15·58	15·70	5·120	0·440	3·159	29·50	18·14
	Effluent water .	69·30	8·03	8·70	0·690	0·060	0·320	0·16	0·10
Sept. 30	Raw sewage .	95·67	18·17	19·50	10·160	0·320	2·708	7·84	5·64
	Effluent water .	69·67	8·26	7·40	0·971	0·008	0·204	0·00	0·00
Average	Raw sewage .	81·91	15·79	16·21	4·819	0·374	2·569	46·53	21·40
	Effluent water .	67·26	8·97	9·17	1·822	0·098	0·613	1·24	0·76

The first set of samples (dated December 11, 1869) were taken continuously, every half-hour, throughout the day, and during heavy rain, by the Royal Rivers' Commissioners, who sealed the samples for the satisfaction of the Company, in order that their identity might be preserved. The second and third sets of samples were taken by Dr. Letheby and Mr. Hawksley during their visits to the works; and the samples dated September the 20th and 21st were taken by Mr. Fewtrell, who went to Leamington for the purpose of securing accuracy in the results. It thus appears that the suspended matters of the sewage are almost entirely removed from it, whilst the dissolved organic matter is reduced from an average of 16·21 grains per gallon to 9·17 of a grain.

The quantity of material used for precipitating the sewage was ordinarily about 28 grains per gallon, and the precipitate, when dried, was generally about three times the weight of the material, a good average being in fact about 80 grains per gallon. Allowing, therefore, for 20 per cent. of moisture in the manure when ready for sale, the average quantity obtained from a gallon of sewage would be 100 grains, or about four tons per day. In the experiments made by Professor Brazier on the sewage of Aberdeen, at the request of the Commissioners of Police, he found that 1 per cent. of the A B C mixture supplied to him by the Native Guano Company, gave from 77 to 120 grains of dry precipitate per gallon of sewage, according to the amount of suspended matter in it. As might be expected, therefore, the chemical composition of the precipitate differs according to the quality of the sewage, and hence the analytical results obtained by different chemists are somewhat discordant. In the following table the sample analysed by the Native Guano Company was obtained by five successive precipitations of sewage with the same deposit. Dr. Voelcker's results are, he says, from samples furnished to him by different parties, and Prof. Brazier's are those obtained from the samples of sewage on which he experimented, the dry precipitate being brought to an uniform proportion of 14 per cent. water.

	Native Guano Co.	Professor Brazier.				Dr. Voelcker.				
		No. 1.	No. 2,	No. 3.	No. 4.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Water . . .	14·1	14·00	14 00	14·00	14·00	7·91	6·12	12 14	8·84	6·30
Organic matter . .	22·4	17·54	24·16	16·25	11·18	19·40	22·45	9·04	12·63	14·55
Phosphate of lime .	9·6	6·02	4·79	5·33	4·10	2·40	2·81	2·57	4·27	2·48
Earthy & alkaline salts	11·2	15·46	10·44	8·01	12·24	23·85	9·93	8·03	8·97	9·12
Insoluble matters .	42·7	46·98	46·61	56·41	58·48	47·44	58·69	68·22	65·29	67·55
	100·0	100·00	100·00	100·00	100·C0	100 00	100·00	100·00	100·00	100·00
Containing nitrogen .	3·46	1·48	2·22	1·44	1·05	0·96	1·92	0·60	0·70	0·67
Equal to ammonia .	4·20	1·80	2·70	1·75	1·27	1·16	2·33	0·73	0·85	0·81

As to the real value of the manure there is a wide difference of opinion between chemists and practical farmers. Dr. Voelcker says that the samples which he has analysed range in value from 14s. 6d. per ton to £1 13s. 6d.; and Professor Brazier states that, according to the expressions of value given to him by Mr. Miller of the Sandeland Chemical Works, the manure which he obtained from the sewage of Aberdeen was worth from £1 19s. 4d. to £3 0s. 9d. per ton. On the other hand, there is the indisputable fact that farmers who have once used the manure, are ready to purchase it again at the commercial price of £3 10s. per ton; and the company has published a long list of testimonials from market gardeners, nurserymen, and farmers, who say that the manure has given most satisfactory results with all sorts of crops, as peas, onions, cabbages, cauliflowers, brocoli, turnips, potatoes, pine-apples, grass, flowers, and shrubs of all descriptions; and the demand for the manure is said to be greater than the means of supply.

Encouraged by the success of the process at Leamington where the works were not constructed for the purpose, the company have extended their operations to other places. At Hastings, for example, they have erected machinery to deal with the whole of the sewage of the place. It amounts to about one million gallons a day, and is furnished by a population of about 30,000 persons. The works are situated upon the seashore, at the eastern end of the town. The sewage flows to them by gravitation, and it is received into a large tank (13 feet by 10) where it is mixed with the A B C material, and agitated by machinery. It then flows into the subsiding tanks, which are 210 feet long and 50 feet wide. After depositing the sedimentary matters, the effluent water is discharged by a weir into the outfall pipe which carries it into the sea. The precipitated mud is removed, as in the former case, and dried by centrifugal machines. It is then mixed with acid, and brought into a saleable condition by drying it upon floors which are heated by the waste steam—the evolved gases

being carried into the furnace fires and burnt. Samples of raw sewage and effluent water sent to us in August last had the following compositions :—

Constituents per gallon.	Raw sewage.	Effluent water
	Grains.	Grains.
Matters in solution . . .	202·67	1113·67
Chloride of sodium . .	136·88	944·00
Organic matter . . .	25·79	45·71
Ammonia	5·440	3·675
Ditto organic . . .	0·310	0·240
Oxygen required to oxydise .	2·418	1·789
Matters in suspension . .	90·64	5·38
Organic matter . . .	33·10	1·66
Mineral ditto . . .	57·54	3·72

The proportions of the soluble organic matters are doubtless too large, for as the residues contained a large amount of common salt, which is very difficult to dry, the loss by incineration includes moisture as well as organic matter. This is clearly shown by the quantities of oxygen required to oxydise them in the two cases. It will, however, be remarked that here, as at Leamington, the sewage has evidently been diluted with other water, for the proportions of chloride in the raw sewage and effluent water are notably different. At Leamington there is a great loss of chloride of sodium, whereas at Hastings there is a considerable gain, from which it may be inferred that fresh water mixes with the sewage in the former case, and sea water gains access to it in the latter. It is very probable at Leamington that subsoil water enters the sewer a little before it reaches the works, and after it has passed the place where the samples of raw sewage are taken—not that the whole of the missing chloride from the effluent sewage is necessarily caused by dilution with other water ; for the experiments of Dr. Voelcker on the absorbing properties of soils have established the remarkable fact that alkaline chlorides are sometimes removed from their solutions by contact with marly soils. In one experiment, for example, which he has recorded in the eighteenth volume of the

Journal of the Royal Agricultural Society, he found that when one part by weight of a marly clay, containing about 46 per cent. of clay, with 12 of sand, and 20 of carbonate of lime, was shaken with twice its weight of the diluted drainage from farm-yard dung, it removed as much as 8·81 grains of chloride of potassium, and 3·95 of chloride of sodium, from each gallon of the liquid. In another case, mentioned in the twentieth volume of the journal, he observed that when two parts of a calcareous clay, containing 52 per cent. of clay, and 25 of sand, with 11 of carbonate of lime, were shaken with 7 parts by weight of liquid manure, they absorbed and removed the whole of the chloride of potassium (2·74 grains per gallon), and 7·04 grains of chloride of sodium; and in a third experiment, with a like proportion of a poor sandy soil, containing 90 per cent. of sand; with 5 per cent. of clay, and only a trace of carbonate of lime, he noticed, as in the last case, that the whole of the chloride of potassium was removed from the liquid, and 1·1 grain of chloride of sodium. The total amount of these compounds in the liquids before and after treatment with the several soils referred to were as follows :—

	Amounts per gallon.		
	Chloride Potassium.	Chloride Sodium.	Total Chlorides.
FIRST EXPERIMENT.	Grains.	Grains.	Grains.
Before treatment with soil . .	35·25	22·85	58·10
After ditto. ditto. . .	26·44	18·90	45·34
Loss per gallon . .	8·81	3·95	12·76
SECOND EXPERIMENT.			
Before treatment with soil . .	2·74	40 35	43·09
After ditto. ditto. .	0·00	33·31	33·31
Loss per gallon . .	2·74	7·04	9·78
THIRD EXPERIMENT.			
Before treatment with soil . .	2·74	40·35	43·09
After ditto. ditto. . .	0·00	39·25	39·25
Loss per gallon . .	2·74	1·10	3·85

Professor Way has also directed attention to the absorptive power of soils for chlorides in a paper published in the eleventh volume of the *Journal of the Royal Agricuctural Society of England* (1850), wherein he says, "Lord Bacon, in his *Sylva Sylvarum*, speaks of a method, of obtaining fresh water, which was practised on the coast of Barbary: Digge a hole on the sea-shore somewhat above high-water mark, and as deep as low-water mark, which, when the tide cometh, will be filled with water fresh and potable. He also remembers 'to have read that trial hath been made of salt water passed through earth through ten vessels, one within another, and yet it hath not lost its saltness as to become potable,' but when 'drayned through twenty vessels hath become fresh." Dr. Stephen Hales, in a paper read before the Royal Society in 1739 on "Some Attempts to make Sea-water Wholesome," mentions on the authority of Mr. Boyle Godfrey, that "sea-water being filtered through some cisterns, the first pint that runs through will be like pure water, having no taste of the salt, but the next pint will be as salt as usual." Berzelius found, upon filtering solutions of common salt through sand, "that the first portions that passed were quite free from saline impregnation." In one of Professor Way's experiments when white clay was shaken up with twice its weight of flax water, the amount of chloride (estimated as chloride of sodium) was reduced from just 90 grains per gallon to 86·78. So also in the experiment before mentioned where 100,000 gallons of Coventry sewage were received into a tank, and then defæcated with Dr. Anderson's preparation of clay and sulphuric acid, the chlorine was reduced from 4·55 grains per gallon to 3·57 grains; and if this be regarded as common salt, the difference will be still more striking, for it is as 7·5 to 5·9. The same fact is often observable when sewage is filtered through common earth; and it is always noticeable in the case of effluent sewage water from irrigated land, even in the driest weather, when instead of being diluted with subsoil

water, it is far more likely to be concentrated by evaporation.

As regards the disappearance of chlorine from the Leamington sewage, the company say that they are charged by the Royal Rivers' Pollution Commissioners with diluting the effluent water with as much as 461 parts of river water to every 100 parts of sewage. This necessarily assumes that 2,600,000 gallons of effluent water leave the outfall daily, whilst only 500,000 gallons of sewage enter the works—an increase which the most unpractised eye would at once detect. The company, therefore, have had the quantity of incoming sewage and of effluent water accurately and continuously gauged by competent and independent parties, who say that the proportions are practically the same, notwithstanding that samples drawn simultaneously with the gauging show a diminution of chlorine from 12 grains to 5 grains per gallon. It has been further ascertained that the temperature of the sewage and effluent water is also the same, when that of the river, which is supposed by the Commissioners to be diluting it to the extent of 4 to 1, is greatly below it. These are remarkable facts and deserve further enquiry; for it is manifest that the Commissioners have been very hasty in forming their opinions, and have not been as free from bias in their account of the process as the importance of the subject deserves.

Very recently the company have greatly improved the system of working, by substituting a cheap form of sulphate of alumina for the expensive alum, and by adopting a more effective and less costly mode of adding the chemicals. They have also resorted to a new method of drying the precipitate by means of steam and hot air, and have thus been able to discontinue the use of the centrifugal machines. They can thus, as we are informed, manufacture the manure at a total cost of 25s. per ton—including all the expenses of working—as materials, wear and tear of machinery, wages, &c.

In addition to the works at Hastings and at Leamington,

the company are about to deal with the sewage of Leeds, Coventry, and Bolton; and they have made an offer to the Metropolitan Board of Works to erect, at their own expense, the necessary machinery for dealing with 500,000 gallons of sewage daily at Barking or Crossness, and, in making this offer, they do not ask for any engagement whatever for the future, but merely wish to demonstrate the practicability of the process as regards the defæcation of the sewage of London, and the profitable manufacture of manure therefrom. This offer the Board has accepted.

PRECIPITATION OF

SEWAGE WITH PHOSPHORIC ACID, MAGNESIA, AND LIME.

When sewage is defæcated with caustic lime, or with the salts of iron and alumina, the phosphoric acid of the sewage is precipitate in the form of an insoluble or nearly insoluble tribasic phosphate, generally of lime (bone-earth) ; but the ammonia of the sewage is left in solution, and is therefore lost. Observing, however, that phosphoric acid will combine with magnesia and ammonia to form an almost equally insoluble tribasic phosphate, in which there are two equivalents of magnesia and one of ammonia, attempts have been made by several chemists to recover the ammonia as well as the phosphoric acid, by means of magnesian salts in conjunction with caustic lime. Sir James Murray, for example, who had devoted great attention to the chemical properties of magnesia compounds, proposed, long ago, that the phosphoric acid and the ammonia of sewage should be precipitated in the form of ammonia-phosphate of magnesia, by the aid of sulphate or chloride of magnesium ; and more recently (in 1853) Mr. Herapath, of Bristol, obtained a patent for "causing the phosphoric acid and ammonia of sewage to be precipitated in a comparatively insoluble state by the addition of magnesia, or a magnesian compound, at or about the same time as the deodorisation of the said sewage is effected by the addition of some chemical agent which will not decompose ammonia or its salts." The agents which he employed were sulphate of iron (one part) and burnt magnesian lime-stone (four parts), and, as we have already

said, the process was tried at the sewage works of St. Thomas, near Exeter, without commercial success. Later still (in 1858), Mr. George Lindsey Blyth, who was at that time the consulting chemist of the Board of Health, obtained a patent for the precipitation of ammonia from sewage by means of a solution of phosphate of magnesia in combination with lime or other precipitating agent. His description of the process is as follows :—Superphosphate of magnesia is first to be prepared by the mutual decomposition of superphosphate of lime and a salt of magnesia, the superphosphate of lime being obtained from bones, bone-ash, apatite, phosphorite, coprolite, phosphate of alumina, phosphate of iron, phosphate of copper, or any other substance containing phosphoric acid, by the aid of sulphuric or muriatic acid, or other acid, the proportions being, in the case of phosphate of lime, one ton of phosphate to half a ton of sulphuric acid of commerce, previously mixed with three times its weight of water, or three-quarters of a ton of hydrochloric acid of commerce diluted with twice its weight of water. These are allowed to stand together for two or three days, being frequently stirred, and then they are mixed with a ton of sulphate of magnesia, dissolved in a sufficient quantity of water, say a little more than its own weight. Powdered charcoal is then added in sufficient quantity (about one ton) to bring the mixture into a solid and convenient form for transport. When used for the purification of sewage it is to be dissolved in water, and added to the sewage in the proportion of five parts of the phosphate to every 100 parts of solid matter in a gallon of the sewage. The whole is then to be well mixed and thoroughly incorporated by means of an agitator. If the sewage does not contain enough free ammonia or other alkali to neutralise and precipitate all the superphosphate of magnesia, lime is to be added, in the form of milk of lime, until the sewage is faintly alkaline to test paper. By this means the ammonia-phosphate of magnesia is thrown down as a flocculent precipi-

tate, which carries with it, after the manner of a clarifier, any insoluble impurities suspended in the liquid. In like manner, instead of lime, he claims the use of any other alkali or alkaline earth, as potash, soda, magnesia or magnesian limestone, or alumina. He thus produces a valuable manure, containing, as he supposed, the ammonia, as well as the nitrogenous organic matter of the sewage, and the phosphoric acid employed ; " while the supernatant liquor being freed from ammonia and nitrogenous matter, liable to undergo putrefaction, becomes deodorised, and may be either applied to the irrigation of land, or run off into the ordinary channels of drainage without fear of creating any nuisance or offence."

This process has never been applied on a large scale, as the unfortunate death of Mr. Blyth, directly after the date of his patent, stopped negotiations which were afoot for the purchase of the invention, and for the use of it, under the management of the author, at Southampton and Leicester.

Theoretically, the process of Sir James Murray was condemned by Dr. Hofmann and Mr. Witt, on account of the supposed solubility of ammonia-phosphate of magnesia in the comparatively large volume of sewage water in which it would have to be precipitated ; for, according to Dr. Fresenius, on whose experiments they relied, the salt is soluble to the extent of one part in 45,000 parts of water containing free ammonia, and in 15,000 parts of pure water ; but its solubility is increased to one part in 7,000 parts of water charged with a salt of ammonia. By a single calculation, therefore, they decided, without reference to experiment, that the process was not available for the profitable defæcation of sewage.

In like manner, Professor Way has reported of Mr. Blyth's process without, in our opinion, submitting it to trustworthy experiment. His remarks on the process are to be found in the " Second Report of the Commission appointed to inquire into the best mode of distributing the sewage of towns, and applying it to beneficial and profitable

uses" (1861); and his experiment is thus described,—"A quantity of soluble phosphate of lime (superphosphate), equal to 31·75 grains of phosphoric acid, and sulphate of magnesia equal to 18·75 grains of magnesia, were added to each gallon of sewage taken from Northumberland sewer on the 24th of March, at 9·30 a.m.; lime-water was then added, sufficient to precipitate the whole;" and the following are the recorded results :—

Constituents per gallon.	Before Treatment.	After Treatment.	Precipitate
Organic matter—	Grains.	Grains.	Grains.
Suspended - - -	24·37	33·84	40·27
Dissolved - - -	12·30		
Lime - - - - -	12·52	21·16	25·71
Magnesia - - -	1·59	18·60	2·36
Soda and potash - -	5·72	8·87	1·29
Chloride of sodium -	34·30	32·83	
Sulphuric acid - -	6·40	46·59	
Phosphoric acid - -	2·48	12·59	21·62
Carbonic acid, silica, oxide of iron, &c. - -	18·22	6·50	14·25
Total per gallon - -	117·90	181·00	105·70
Ammonia - - -	7·88	7·81	2·37
	In solution.		

The composition of the dry precipitate thus obtained was as follows :—

Organic matter . . .	38·09
Lime	24·32
Magnesia	2·23
Phosphoric acid . . .	20·45
Carbonic acid	5·79
Silica, sand, oxide of iron, &c. .	9·12
	100·00

The organic matter contained nitrogen = 2·24 ammonia. It is not possible to understand the results of this experiment, for it is well known that, independently of the precipitating power of the salts of magnesia in conjunction with lime, lime itself is capable of removing phosphoric acid from its solutions in a most complete manner, when the alkali is added in sufficient quantity to neutralise free acid, and to form tribasic phosphate of lime. Even Mr. Way's own experiments in the two cases which precede the magnesian process, show that, with from fifteen to sixteen grains of quick lime per gallon of sewage, the whole or nearly the whole of the phosphoric acid is precipitated. In one case, to use his own words, five-sixths of it are thrown down, and only 0·45 of a grain per gallon is left in solution. In the other case all of it is recovered, there being left but a mere trace of it in solution. How, therefore, in this experiment with Mr. Blyth's material, as much as 12·59 grains per gallon, or rather more than one-third of the whole of the phosphoric acid present should have escaped precipitation is altogether beyond our comprehension. Nor can we understand how with only 36·67 grains of organic matter in the original sewage, as much as 74·11 grains are obtained in the two products. There are also discrepancies in the analysis of the dry precipitate, which give additional weight to the conclusion that the experiment is not reliable. It may be that the process does not remove ammonia from sewage to the extent that Mr. Blyth imagined; but it certainly cannot be said of it that it fails to recover the phosphoric acid used, and that, therefore, "it is the most costly of all the plans that have been proposed" for defæcating sewage. In our own experiments—made at the time of the patent, as well as recently—we ascertained that sewage was very perfectly purified by the process; and that when a proper amount of lime was used, the whole of the phosphoric acid employed was recovered, together with no inconsiderable portion of that contained in the sewage. In two experiments on sewage of different strengths, with a

quantity of the material containing 10·30 grains of phosphoric acid, and then an excess of lime, the results were as follows :—

Constituents per Gallon.	London Bridge Sewage		Coventry Sewage.	
	Besore Treat-ment.	After Treat-ment.	Before Treat-ment.	After Treat-ment.
	Grains.	Grains.	Grains.	Grains.
Soluble Matters—	68 33	90·02	46·61	68·07
Chloride of sodium -	16·05	14·86	7·91	7·00
Phosphoric acid -	0·64	0·60	0·53	0·C5
Organic matter -	16·91	11·26	5·84	3·45
Ammonia - -	6·33	6·24	1·16	1·06
Do. organic - -	0·79	0.63	0·22	0·10
Oxygen required for oxydation - -	2·54	1·41	0·78	0·43
Suspended Matters—	47·42	0·00	21·11	0·00
Organic matter -	27·51	0·00	8·87	0·00
Mineral do. -	19·91	0·00	12·24	0·00

The percentage composition of the dry precipitated matters from the original sewage, and from the sewage when treated with Blyth's superphosphate of magnesia, were as follows :

Chief constituents.	London Bridge Sewage.		Coventry Sewage.	
	Before Treat-ment.	After Treat-ment.	Before Treat-ment.	After Treat-ment.
Organic matters . .	57·89	28·06	41·02	12·16
Phosphate of lime .	3·11	27·11	2·89	32·65
Earthy matters, &c. .	14·65	35·30	15·87	45·60
Sand, &c. . . .	24·35	9·53	40·22	9·59
	100·00	100·00	100·00	100·00
Containing nitrogen—ammonia . .	3·11	1·61	2·50	0·99

In both these experiments the lime was added to the sewage in great excess, as the object was to ascertain whether the phosphoric acid would be retained in the solution, as Mr. Way supposed; but as this is manifestly not the case, there is no reason why, in practice, the lime may not be reduced to the minimum proportion necessary for the precipitation of all the phosphoric acid. In Mr. Way's experiment, already referred to, the quantity of lime was evidently deficient, and hence there is no excess of earthy salts; but in an experiment by Mr. Hurtslett on sewage from the same sewer, the earthy matters, according to an analysis made by Mr. Way, did not exceed 9·64 per cent. of the imperfectly dried precipitate. The results of these analyses, as reported by Mr. Way, are as follows:—

Composition of the precipitate obtained from Sewage of Northumberland street Sewer, by means of Blyth's process.

	Mr. Way's experiment.	Mr. Hurtsletts' experiment.
Moisture	0·00	8·10
Organic matter	38·09	58·11
Phosphate of lime	44·56	8·66
Carbonate of magnesia	2·45	0·43
Carbonate of lime	0·37	8·29
Sulphate of lime	?	0·92
Alkaline salts	?	0·38
Silica, oxide of iron, &c.	9·12	15·11
	100·00	100·00
Nitrogen equal to ammonia	2·24	4·50

In Mr. Hurtslett's experiment the original sewage contained 98·4 grains of soluble matters per gallon, and 21·6

grains of suspended matters. When this sewage was treated with Blyth's materials in the proportions of 1 ton 3 cwt. of the superphosphate compound, and 4 cwt. of lime, to every million gallons of sewage, the dry commercial precipitate amounted to 3 tons 8 cwt. ; and, according to Mr. Way, it had the composition above stated. The value of the precipitate was estimated at £3 14s. a ton ; and it was calculated that it cost £1 15s. a ton to produce it—100 tons, in fact, of the precipitate, worth as a manure £370, would cost for materials and labour £175 ; and, therefore, they would yield a profit of £195. Subsequent experience has shown that the magnesian compounds may be omitted from the mixture, and that the precipitated phosphate of lime is quite as available for plants as the original superphosphate.

PRECIPITATION OF

SEWAGE WITH PHOSPHORIC ACID, ALUMINA AND LIME.

In the month of August of last year (1870) a patent was obtained by Mr. David Forbes, F.R.S., and Dr. Astley Paston Price, for the treatment of sewage with an acid solution of natural phosphates of alumina, either alone or in conjunction with lime or carbonate of lime. In carrying out the invention they say "we firstly submit to the action of sulphuric or muriatic acid the natural phosphates of alumina; which phosphates of alumina are capable of being decomposed and rendered soluble by the employment of sulphuric or muriatic acid. Having converted the phosphates into a soluble condition, or having obtained a solution of the phosphates of alumina, they may either be employed in their concentrated form, or a solution of the same may be diluted, and they are then in a fit and proper condition to be employed for the treatment of sewage. Whilst the sewage is contained in a cistern or reservoir, or whilst it is in the act of flowing thereinto, the requisite proportion of the soluble phosphates of alumina is to be added thereto, and after thorough admixture with the sewage by the use of agita-

tors, or other well-known means, the sewage so treated may be allowed to remain tranquil in the reservoir in order that subsidence of the resulting precipitate may be effected, or after having added to the sewage the requisite amount of the soluble phosphates of alumina, lime (by preference in the form of milk of lime) is to be added in such quantity as that the phosphates in solution shall be precipitated. This result will be known by the sewage acquiring a neutral or alkaline reaction, or the lime may be firstly added, and the solution of the phosphates of alumina added subsequently, but we prefer the former process, or the soluble phosphates of alumina may be firstly decomposed by means of lime or carbonate of lime, and the resulting precipitate may be employed for the purpose of effecting the separation of certain constituents of sewage."

"In conjunction with any of the before-mentioned methods of carrying out our invention, deodorising agents, such, for example, as animal or vegetable charcoal, may be employed, but good results will be obtained by the employment of the phosphates of alumina alone, or in conjunction with lime as before mentioned. The sewage, after treatment by either of the before-mentioned processes, is allowed to settle, and the clear or supernatant water may be run off, and the deposit or precipitate collected and removed, and employed for agricultural purposes either in the moist condition, or after having been submitted to a drying or desiccating process. Or the precipitated phosphates may be again submitted to the action of sulphuric acid, and the solution be again employed for the treatment of sewage in a manner similar to that before described. The proportions in which the soluble phosphates of alumina may be employed will vary with the sewage to be operated upon, and the quality of the manure desired to be obtained. We have obtained good results by the employment of about two parts by weight of the soluble phosphates of alumina to every one thousand parts by weight of sewage treated, but we do not limit ourselves to such proportions."

The natural phosphate of alumina to which the patentees especially allude is that which occurs in large quantities in the West Indian Islands, and which was mistaken at first by several chemists for phosphate of lime. It consists, according to Mr. Forbes, of one equivalent of alumina with one of phosphoric acid, and five of water. The percentage composition of three commercial samples analysed by him was as follows :—

	No. 1.	No. 2.	No. 3.
Phosphoric acid -	38·96	37·09	33·11
Alumina - -	27·06	26·08	24·57
Peroxide of iron -	2·68	2·76	2·07
Lime - - -	1·94	2·09	1·03
Insoluble matter -	6·70	9·10	17·00
Water, &c. - -	22·66	22·88	22·22
	100·00	100·00	100·00

At present this material has no commercial value, and it occurs in such enormous quantities that, on one island alone, the report of the survey estimates the deposit at no less than 9,000,000 tons.

The patentees lay stress on the fact that the sewage water, when thus defæcated, may be utilised, if necessary, by irrigation, and in that case there is no occasion to precipitate the soluble phosphates with lime, as the clarified water is sufficiently pure to be run upon the land without causing offensive effluvium or slimy deposits. In point of fact, the effluent water may be so charged with soluble phosphates as to render the land fit for the purpose of growing grain or other crops which cannot now be produced from irrigated land without the use of rich mineral manures. "In other words," says Professor Forbes, "our process is the first attempt made to strengthen the otherwise miserably weak sewage water, and at the same time so far to effect its purification that it can be employed without offence." But the grand point in the process is that whilst it renders sewage so pure that the defæcated

water may be safely admitted into any neighbouring water course, the deposit may be made to contain any proportion of phosphate of lime, and, therefore, to be of sufficient value to pay the cost of carriage to a distance. Its value, indeed, may be increased at pleasure to any extent, up to that of almost pure bone-earth, so that, although a small quantity of the material will clarify sewage sufficiently well for sanitary purposes, yet it is best to use it in large proportions, such as not less than two tons of the natural phosphate to a million gallons of sewage, and this will produce from four to five tons of manure, with from fifteen to eighteen per cent. of phosphoric acid, or rather from thirty-three to thirty-nine per cent. of phosphate of lime (bone-earth) in a soluble form. It may even be made richer than this, for a sample of the deposit obtained from ordinary London sewage with about forty-seven grains of the material per gallon of sewage, which is at the rate of three tons of the natural phosphate to a million gallons of sewage, gave a deposit which, according to Dr. Voelcker, had the following percentage composition :—

Moisture evolved at 212° F. - - - -	3·98
Organic matter and water of combination	20·11
Phosphoric acid - - - - - -	28·52
Lime - - - - - - -	13·09
Alumina, oxide of iron, magnesia, &c. -	29·95
Insoluble siliceous matter - - -	4·35
	100·00

The organic matter contained 0·57 nitrogen, equal to 0·69 ammonia.

In this case the 28·52 phosphoric acid was equal to 62·26 of tribasic phosphate of lime, which was no doubt in a hydrated condition, and, therefore, readily available for plants, like soluble phosphate. Dr. Voelcker says of it that "it possesses valuable fertilising properties, and, in my opinion, a sewage manure equal to the sample analysed by me, will command a ready sale at £7 7s. a ton."

In some recent experiments with a sample of the natural phosphate supplied to us by Mr. Forbes, we found that thirty-three grains of it, containing 10·38 grains of phosphoric acid, dissolved in its own weight of commercial sulphuric acid, and added to a gallon of London and of Coventry sewage, gave the following results :—

Constituents per gallon.	London Sewage.		Coventry Sewage.	
	Before Treatment.	After Treatment.	Before Treatment.	After Treatment.
	grains.	grains.	grains.	grains.
Soluble matters . .	68·33	100·07	46·61	82·59
Chloride of sodium .	16·05	15·57	7·91	7·01
Phosphoric acid . .	0·64	0·68	0·53	0·60
Organic matter . .	16·91	10·99	5·84	3·60
Ammonia . . .	6·33	5·70	1·16	1·04
Do. organic. . .	0·79	0·56	0·22	0·14
Oxygen required for oxydation .	2·54	1·44	0·78	0·47
Suspended matters. .	47·42	0·00	21·11	0·00
Organic matter . .	27·51	0·00	8·87	0·00
Phosphoric acid . .	0·68	0·00	0·28	0·00
Mineral matter . .	19·23	0·00	11·96	0·00

These results show that the defæcation of the sewage was very complete as regards the precipitation of suspended matters, and that a large proportion of the soluble organic matter had also been removed. The percentage composition of the dry precipitate was as follows :—

	From London sewage.	From Coventry sewage
Organic matter - -	24·80	10·41
Phosphate of lime - -	16·82	22·11
Carbonate of lime and magnesia - - -	49·39	58·14
Silica, &c. - - -	8·99	9·34
	100·00	100·00

The organic matter contained nitrogen equal to ammonia - - -	1·41	0·91

In these cases, as in the last with Blyth's superphosphate of magnesia, an excess of sulphuric acid and lime was used to precipitate the whole of the phosphoric acid, and hence the earthy carbonates are in great excess; but no doubt this can be avoided in practice on a large scale, as is shown by the comparatively small proportion of lime (13·09 per cent.) in the precipitate analysed by Dr. Voelcker.

This process has not yet been tried on a large scale, and, therefore, we are unable to speak of its actual commercial value, but it is evidently very promising; for if two tons of the natural phosphate of alumina, costing about £7, will yield from four to five tons of manure, with from 33 to 39 per cent. of what may really be called soluble phosphate of lime, there is every prospect of its being remunerative; besides which, it is unquestionably very effective in its defæcating power, for it immediately removes from the most fœtid sewage its turbidity, its colour, and its offensive odour; and though, as Mr. Forbes says, it does not render the water fit for drinking purposes, yet it makes it as clear and colourless as ordinary river water, and so innocuous that it can be taken into the mouth, and even drunk without repugnance. Fishes can live in it, and most important of all, it will remain for months in hot summer weather without showing any tendency to putrefy or emit a disagreeable odour. There is no doubt, therefore, that such water may be freely and safely discharged into a water-course, or used for irrigation purposes.

DISINFECTION WITH EARTH, Etc.

EARTH CLOSETS.

The disinfecting power of earth has been known from the earliest time; in fact, the burial of the dead and the putting of unclean things into the ground are examples of its use from the remotest antiquity. Iu the ordonnances of Moses, which were written for the guidance of the Israelites, specific instructions are given for the disposal of the blood of slaughtered animals, by pouring it upon the ground, and of "that which cometh from thee," by putting it into the earth and covering it therewith, so that the camp may be clean and holy; and again, the custom in China of mixing earth or fat marl with human excrements, and so forming them into a portable and odourless manure is of very ancient date. It is somewhat surprising, therefore, that among all the inventions in this country for the disposal of human excreta, there have been none, until recently, for the disinfection and consolidation of them by means of common earth. Rosser, in 1837, obtained a patent for the treatment of fæcal substances, urine, and house refuse with herbaceous plants and common earth, to which were added unslaked lime, soot, powdered gypsum, &c. Twenty years later, the Rev. W. R. Bowditch,

one of the vicars of Wakefield, who had been studying the absorbent action of clay in the impurities of coal-gas, recommended, in the *Journal of the Agricultural Society* for 1858, that dry pounded clay should be put into a chamber or cistern above the closets of houses, and distributed over the fæces, &c., by means of some mechanical contrivance, to be worked by a handle, there being a water-tight box below, which could be moved away and emptied when necessary. About the same time the Rev. H. Moule, who is the vicar of Fordington, in Dorsetshire, had practically tested the deodorising power of earth on privy soil; for having abolished the cesspools of his house, on account of their unwholesome and offensive nature, he substituted small buckets, which were placed beneath the privy seats, and these were emptied daily into a trench in his garden, where the foul matters were immediately covered with earth. He soon noticed that when the trench was reopened the matters from the closet had not only lost their offensive odour, but had actually disappeared by a process of disintegration. This led him to the experiment of putting earth into the buckets, and of drying the contents in a covered shed. After working in this manner with about a load of earth, and redrying it, he found it was so perfectly inoffensive that he could use it over and over again, at least a dozen times in succession, and thus he produced a valuable manure, containing about one-third of its weight of dried excrement. The next part of his inquiry was devoted to the mechanical process of supplying the dry earth to the closet instead of water; and in the month of May, 1860, he obtained a patent, in conjunction with Mr. James Bannehr, for "improvements in the nature and construction of closets and commodes for the reception and removal of excrementitious and other offensive matter, and in the manufacture of manure therefrom"—his claim being for the use of dry earth, clay, loam, or peat, powdered and sifted, and applied to the excrementitious matters, by means of certain mechanical contrivances, so as to substitute a dry closet or commode for a water-closet, the

earth, &c., being repeatedly used in this manner after it had been properly dried. Since that time a number of patents have been taken out for improvements in the machinery of the apparatus, the best form of it being that which is used by the Earth-closet Company and patented by their engineer, Mr. Girdlestone.

Experience has shown that the quality and condition of the earth employed in the closets have much to do with the success of the process, for pure or nearly pure sand has little deodorising power; and the same is the case with chalk, and other forms of carbonate of lime. Peat also, although rather more effective than sand or chalk, is not a good deodoriser; whereas clay, or earth which is rich in clay, is well suited for the purpose. The degree of dryness is also a matter of considerable importance, as it seriously affects the absorbent power of the material—hence the necessity for selecting a heavy soil, like brick-earth, which is loaded with clay, and then drying it by artificial means, in order that it may be powdered and sifted for the purpose of utilizing its absorbent action to the fullest extent.

As to the quantity of earth required on each occasion, it appears, from observation and experiment, that about half a pound of dry earth is sufficient for each solid evacuation (amounting to from four to five ounces in weight), and thrice as much for each liquid discharge (amounting to six fluid ounces in bulk). Practically, indeed, it is found that 4½ lbs. of dry earth per head per day is sufficient for all purposes, and in illustration of this a few working examples may be given. In the Dorset County Gaol at Dorchester, where the inmates are all adults, three pounds of earth are used per head daily, but the product is wet and offensive, showing that the quantity of earth is not enough for the proper consolidation and deodorisation of the excreta; whereas, at the Dorset County School in the same town, with eighty-three boys, a ton of artificially dried earth is used in the four closets weekly. This is at the rate of 4 lbs. per head daily, and it forms a solid in-

offensive compost. At the villages of Halton and Aston Clinton, on the estate of Baron Rothschild, near Wendover, in Buckinghamshire, there are fifty-five well-managed earth closets, of good construction. These accommodate about 300 people, and during the last four years they have been supplied with dry earth at the rate of 130 tons a year, which is in the proportion of rather less than $2\frac{3}{4}$ lbs. per head daily, but the closets do not receive the whole of the day urine. In Lancaster also, where there are 90 earth latrines with 200 seats, accommodating 2,250 persons, belonging to 450 houses, the quantity of earth used is 14 tons a week, which is a little less than 2 lbs. per head a day; but, as in the last case, a good deal of the urine is not discharged into the latrines. Again, at the volunteer camp at Wimbledon, the experience of the earth system is particularly instructive, for there are 114 latrines fitted up with earth closets in the most complete manner, and 41 urinals with earth-pits for the absorption of the urine. All the contrivances have been arranged by Mr. Girdlestone, the engineer of the Earth-closet Company, and they have been kept in good working order. Dr. Buchanan has ascertained, from careful inquiry at the camp, that during the meeting of the volunteers, which lasts for fourteen days, as many as 3,000 persons use the closets daily, and 10,000 the urinals. In the course of that time 140 tons of dry earth are expended in the closets and urinals, the closets requiring 4,500 lbs. per day, and the urinals 17,900 lbs. This is in the proportion of 1·5 lb. of earth for each operation at the closets, and 1·79 lb. for each visit to the urinals. When the earth was dry and of good quality it was found that the product was solid and inoffensive; but when, as in the preceding year (1867), it was of a peaty nature, the compost was wet and sour. Taking these facts into consideration, Dr. Buchanan concludes that $4\frac{1}{2}$ lbs. of dry earth would be a proper supply for each person daily, $1\frac{1}{2}$ lbs. being allowed for each visit to the closet or urinal, and three such visits daily. A village of 1,000 inhabitants would, therefore, require 500 lbs., or just two tons of dry earth per diem.

The method of using the earth will necessarily vary according to circumstances. At Lancaster, where the latrines are under the superintendance of the local authorities, the earth is thrown into the closets in one application daily, or it may be supplied by a scoop after each operation, as at the Dorset County Gaol; or, better still, by proper contrivances for ensuring a regulated delivery of earth, as in the patent earth-closet or commode of the company; and the foul earth may be removed from the pit or vessel at any convenient time up to two or three months. After its removal it may be again dried and returned to the closet, until it has become charged with materials of manurial value.

The importance of this arrangement in a sanitary point of view is considerable, especially in warm climates, where the desiccation of the earth is easily effected. This has been clearly established in India, where the system has been rapidly extended. Earth-closets were first used in Bengal in 1865 for the accommodation of the British regiments, and they were also partially adopted in the gaols of that presidency. In the following year they were extended to the regimental latrines of Bombay, and from thence to Madras, so that before the close of 1867 they were found to be so useful and free from offensive smell, as to be generally employed in all the barracks, gaols, hospitals, and public institutions of the three presidencies of India. At first there was a little prejudice against them, on account of their being improperly managed, sufficient care not having been bestowed on the condition of the earth, as regards its dryness and disinfecting quality, but when this was remedied by instructions from the Government as to the right management of the system, and the disposal of the manure, the earth closets came rapidly into favour, and before the close of 1867 the authorities of India were able to report to the Secretary of State that Mr. Moule's system had been generally adopted in India, and had been found to be a great public benefit. The same has been the case in this country, where the system

has been used with proper supervision, as in barracks, hospitals, lunatic asylums, gaols, schools, and large manufactories. Even in small villages where the landlords or local authorities have properly attended to the system, it has been found to work well, without causing the least offence, and without fouling the soil in the neighbouring streams.

As regards the value of the product, it seems, like all such materials, to be variously estimated, according to the quality and the demand. In the city of Lancaster, where the material is mixed with the refuse of the shambles, and with urine from some of the public urinals, it realises only from 7s. 6d. to 10s. per cubic yard, and it just pays its expense. At the Dorset county gaol it sells for £1 a ton, or 10s. per head, per annum, but at the county school in the same town, it fetches from £2 to £3 a ton, or 15s. a head. In the experiments of the Rev. H. Moule with material that had been used in the closets five times over, it was found that, when contrasted with super-phosphate at £7 12s. a ton, its immediate results were equally good, and its permanent effect on the land much better. In both cases the manures were employed in the same quantities, namely, in the proportions of one cwt. to an acre of land. We are not acquainted with many chemical analyses of the product, although two have been published by Dr. Hawksley, which were made by Mr. Evans, of Leadenhall street, both of them being of material that had been used only once in the closet, and the results are as follows :—

Organic matter, &c.	5·16	22·65
Soluble phosphate of lime	0·53	1·10
Potash	1·06	1·10
Alkaline salts	—	4·10
Aluminia, sand, &c.	—	71·05
	100·00	100·00
Nitrogen equal to ammonia	0·33	0·79

These samples were valued by Mr. Evans at £1 and £1 10s. per ton respectively, but it is evident that if the

material had been used four or five times over, it would have been considerably more valuable than this.

The cost of working the system has been carefully computed by Dr. Buchanan, who says that in a village of a thousand people it would be £260 a year, and that the value of the manure (say 720 tons at 10s. per ton) would be £360, supposing that the earth had been used only once; but if employed four times over, the annual outlay would be reduced to £244, and the product, amounting to 200 tons a year, would, at £3 a ton, the price at Dorchester, and the estimated value of it by Mr. James, the agent of Baron Rothschild, realise £600 a year. Even at the approximative value of 10s. per head of the population, it would be worth £500; and this, he thinks, would be a profitable return, helping to pay the cost of other sanitary work. In fact, the advantages of the system, as summarised by him, are as follows :—

"1. The earth closet, intelligently managed, furnishes a means of disposing of excrement without nuisance, and apparently without detriment to health.

"2. In communities, the earth-closet system requires to be managed by the authority of the place, and will pay at least the expenses of its management.

"3. In the poorer classes of houses, where supervision of any closet arrangements is indispensable, the adoption of the earth system offers especial advantages.

"4. The earth system of excrement removal does not supersede the necessity for an independent means of removing slops, rain water, and soil water.

"5. The limits of application of the earth system in the future cannot be stated. In existing towns, favourably arranged for access to the closets, the system might at once be applied to populations of 10,000 persons.

"6. Compared with the water-closet, the earth-closet has these advantages :—It is cheaper in original cost; it requires less repair; it is not injured by frost; it is not damaged by improper substances being thrown

down it; and it very greatly reduces the quantity of water required by each household.

"7. As regards the application of excrement to the land, the advantages of the earth system are these:—The whole agricultural value of the excrement is retained; the resulting manure is in a state in which it can be kept, carried about, and applied to crops with facility; there is no need for restricting its use to any particular area, nor for using it at times when, agriculturally, it is worthless, and it can be applied with advantage to a great variety, if not all, crops and soils."

On the other hand, the chief objections to its use are—the notion of its filthiness as contrasted with the cleanliness of the water-closet, and the difficulty of supplying the necessary quantity of dry earth, and of removing the foul compost. The advocates, in fact, of the present water-closet system assert that water is a vehicle which will carry the filth, by the natural power of gravitation, to any place where it is wanted; and that it carries it more cleanly, more cheaply, and more immediately than can be done by any organization of man and horse and cart. "The manure which must be collected from town privies by an army of scavengers, and distributed from the depôt by barge and rail, to be afterwards loaded in carts and spread abroad by hand, and covered by the plough, might, if water were the carrier, be virtually self-borne to the very place were it is wanted,—taken almost direct from the water-closet to the field, and there washed in at once with really no labour at all among the very roots of the plants it is to feed." But all this assumes the total absence of inconvenience and danger from misadventure of the soil between the closet and the field, and it assumes, moreover, that the ground is always ready to receive it and the growing crop to appropriate it,—that there will, in fact, be no escape of noxious effluvium into the air, or of foul matters into the earth or into the neighbouring water-courses. Experience, however, has shown that these

assumptions are never realised in practice, and that the greatest difficulties of the water-closet system are created by the very circumstances which are thus assumed to be non-existent,—that the vehicle itself, which is said to be so admirable a servant, is really a tyrannical master, defying all our efforts to control it ; and hence there are many large towns already sewered which will not accept this vehicle, notwithstanding its plausible show of convenience. "If there were no question," says Dr. Buchanan, in his report to the Privy Council on this subject, "of wasting the excrement, of nuisance and injury to health by its decomposition, or of river pollution (and he might have added of subsoil infection), certainly excrement removal by sewers has the advantage claimed for it. But the objectors probably mean more than this, for they not only say that the water-closet system becomes more available as the size of the town increases, but they also say that the earth system becomes less available. They appear to think that in a closely-built town, the whole traffic would be at the mercy of an army of scavengers. Now, this would be true to about the extent, and no more, that such a town is now given over to coal merchants, for, roughly speaking, a town would want about as much earth to be as often supplied to it for its closets as it requires of coals to be supplied for its fires ; and removal, which need not be more frequent than supply, would mostly be done by return carts." Dr. Hawksley has entered very fully into this part of the question, and his conclusions are that any town or city might easily be divided into sections of a thousand houses, and these again into sub-sections of a hundred each, which might be easily managed and kept in order by a man and boy, with a single waggon, the dry earth being supplied to each house, and the compost removed therefrom every two days, cinder dust and vegetable refuse being carried away at the same time. Now, assuming that there are six persons in every house, and that each person would require four and a half pounds of dry earth per diem, the quantity of such earth to be

delivered to the fifty houses in the day would be only 1,350 lbs., or a little more than twelve hundredweight; and as the average amount of excrement, solid and liquid, in a mixed population amounts daily to 39·1 ounces per head (viz., 2·8 ounces of solid, and 36·3 of liquid), it is evident that the waggon would have to return with an additional weight of 733 lbs., or about six and a half hundred weight, making a total of nearly a ton, and to this must be added about half a ton of dust and refuse.

Since the above was written, we have been informed by the Rev. H. Moule that his experiments on the disinfecting power of earth were begun in the early part of 1858, when he abolished the cesspool of his house, on account of its dangerous proximity to the well, and substituted small buckets beneath the seats of the closets. After noticing the disinfecting and deodorizing power of the earth of the trenches, into which the contents of the buckets were emptied, he adopted the plan of mixing the contents of the buckets daily with dry sifted earth, and leaving it to consolidate in a shed. About three cart-loads of earth were used in this manner during a period of five or six weeks, for a family of seventeen persons; and at the end of that time he found that the first portions of earth were sufficiently dry to be used again. It was while using the same earth for the fifth time that he published the results of his experiments, and inaugurated his system—saying that it was founded on the rapid and effectual disinfecting power of dry earth; on the capability of using the earth again and again, until it became rich as a manure; and on the fact that the system dealt with the sewage and cesspool difficulty at its very source. He then devised the mechanical means of using earth in an ordinary closet or commode, and in 1860 he obtained his patent for it. He ascertained that a pint and a half of dry earth was sufficient for each visit to the closet.

He informs us, moreover, that his system was first used in Bengal in 1863, by Dr. Mouat, Inspector-General of Gaols in that Presidency; and that before June, 1864, it

was established in many public institutions, including thirty or forty gaols, and Mr. Moule's paper was reprinted from the *Journal of the Society of Arts*, by the Sanitary Committee of Calcutta, and translated into Punjabee. In 1865 a committee was appointed to inquire into the working of the system; and before the close of 1867 the committee reported to the Secretary of State for India that Mr. Moule's system had been generally adopted in India, and found a great public benefit. In acknowledgement of Mr. Moule's services, the Governor-General in Council made him a grant, which was sanctioned by the Secretary of State for India, of the sum of £500.

COLLECTION AND DISPOSAL OF NIGHT-SOIL BY MIXING IT WITH ASHES OR OTHER ABSORBENT SUBSTANCE.

Although dry earth is manifestly the best absorbent for the treatment of human excreta, yet many other substances, as ashes, street-sweepings, various kinds of carbonaceous matters, and the solid refuse of different branches of industry have been proposed for the same purpose. Mr. Stanford recommends the use of charred sea-weed instead of dry earth, as it is a more effective absorbent, requiring only one-third of the weight to do the like service ; besides which, he says, the compost is more easily dried, and may be reburnt in closed retorts, so as to recover the ammonia and fixed salts, and yield a charcoal which is fit for further use. According to Mr. Stanford, a hundredweight of the charcoal is sufficient for a closet used daily by six persons for a month, and the product containing all the excreta could be removed without the slightest offence. Liebig is of opinion that bog-turf in coarse powder is a good absorbent material, and forms with sewage matters an excellent manure.

Among the numerous patents relating to this subject are those of Poitivin (1835), Hompesch (1841), Du Boisson (1845), Rogers (1848), Tarling (1850), Gilbee (1852), Perks (1852), Macpherson (1853), and Herapath (1854), for the use of different kinds of carbonaceous matters, as ashes, breeze, and the coke or charcoal of peat, vegetable mud or mould, tan, sawdust, rags, schist, bog-head coal, &c. Besides which there are the patents of Rosser (1853), Goux (1865), and others, for the utilisation in this manner of all sorts of vegetable and animal refuse, as chaff, spent dye-stuffs, dry horse-dung, shoddy, refuse wool, &c.

In many large towns of England and Scotland, where sewerage works are but partially constructed, or where, from the difficulty of disposing of sewage, the use of water-closets is not encouraged, absorbent substances are employed for the consolidation of night-soil, and they are either placed at once in the pits beneath the privies, as in the middens of Lancashire, or they are put into moveable boxes or troughs beneath the privy seats, or they are mixed with the soil after its removal from the house.

When the midden is well placed, and is well constructed, so as to prevent the escape of its fluid contents into the ground, and of rain or other water into it, the compost is not offensive unless it is allowed to accumulate to too great an extent. At Manchester, where, according to Sir Joseph Heron, the town clerk, it has been found necessary to prevent, as far as possible, the discharge of sewage from the town into the River Medlock, which is already extremely foul from trade and manufacturing refuse, no encouragement is given to the water-closet system, and, therefore, among the poor, privies with middens are the most usual kind of accommodation; indeed, of the 70,000 houses of the town, only about 10,000 have water-closets, and the rest are accommodated with 38,000 out-door midden-closets, which are regulated by certain bye-laws of the Corporation as to their situation, construction, dimensions, ventilation, drainage, &c.—the object being to prevent, as far as possible, the escape of noxious matters

into the air or soil by keeping the contents of the midden dry, by having the pit impervious to water, and by insuring the proper distribution of the ashes upon the night soil. This is effected by various contrivances which are more or less successful, and the contents of the middens are removed by the scavengers of the town, who keep the key of the midden door. In this manner about 120,000 tons of night-soil and ashes are removed from the middens annually, and they are sold at an average price of 1s. 6d. per ton. They are sent by rail, in the Corporation waggons, to Yorkshire, Nottinghamshire, and Lincolnshire, the cost of the carriage being from 3s. 6d. to 7s. per ton. The sale of the manure thus obtained realises about £9,000 per annum, and the cost of the scavenging is nearly £17,000.

There is no doubt that the middens of Manchester are not as well constructed or as well managed as they might be, for they are too large, and are emptied at too long an interval (four months). They are, therefore, generally offensive ; in fact, according to the report of Mr. Greaves, the Consulting Medical Officer of the Chorlton Union, they are frequently the cause of pythogenic diseases. At Liverpool, also, where the midden system is imperfectly managed, it is a prolific source of disease, and is emphatically condemned by the Medical Officer of Health, Dr. Trench, who has used his utmost endeavours for some years past to abolish them, and has, indeed, mostly since the year 1866, effected the conversion of 14,393 privies into water-closets, there being, however, still in Liverpool about 20,000 privies attached to ashpits. The cost of this change to the Corporation has been not less than £40,000, it having been found necessary, on account of the poverty of the landlords, to make an advance to them of from £3 10s. to £7 10s. for each closet or set of closets. But at Nottingham, where the middens are better placed, better constructed, and apparently under better management, they are not found to be at all objectionable ; for all the houses of the poor have privies in the back yards.

They are placed as nearly as possible together, over water-tight pits, which receive the ashes in such a manner as to distribute them over the soil ; but when there is not room for a proper midden the closet is provided with a portable wooden box, which is replaced daily. The solid contents of the pits are removed by the town scavengers every two or three months, and they are carried to the manure wharf upon the canal where they are at once emptied into barges. When a barge is full it is immediately taken away, and its contents are sold to farmers at various points along the course of the canal, the price realised being from 3s. to 4s. a ton, according to distance. In this way the manure, amounting to about 40,000 tons a year, is readily disposed of at a price which pays about two-thirds of the cost of scavenging the town. At Hull, where the midden system is almost universally practised, the old fashioned pit is being gradually abolished and replaced by a small midden closet of peculiar construction. It is thus described in the Appendix to the Twelfth Annual Report of the Medical Officer of the Privy Council. "The space under the seat forms the entire receptacle for all the ashes, refuse, and excrement of the house, and is built of bricks in cement, with a bottom of brick or flag, sloping from the level of the paved floor in front to a little below the ground level at the back, and forming only a very shallow pit. Into this space, through a hole in the privy seat, all dry refuse is thrown with a scoop, and as a rule the closet seat is not messed in the process. The front of the middle space is formed by the front board of the closet, and is made moveable to give the scavenger access to the pit. There is no drain to it, but as there are plenty of ashes, and as in practice slops are thrown down the drains, the contents of the closets are almost invariably dry, and are removed by a spade without difficulty." The town consists of 26,000 houses, and it is divided into forty-six districts, each district being let to a separate contractor, whose sole business is with the middens of the town, everyone of which he is required to empty at least once in a week ; and the cost

of this work is about £2,000 a year to the Corporation, the contractor having all the refuse for his own profit. Where the middens are well attended to by the occupants they are quite free from offence, but when they are improperly used or are neglected they are undoubtedly a nuisance. The same is the case at Salford, Halifax, Bolton, Preston, Leeds, Birmingham, Stamford, Macclesfield, and many other places where the old fashioned midden system is more or less in operation ; and to avoid this attempts have been made to collect the night-soil in tubs or boxes lined or otherwise charged with some absorbent material. At Nottingham, for example, a little earth is put into the box before it is placed beneath the privy. At Salford, according to the report of Dr. Syson, the Medical Officer of Health, the most successful results have been obtained from a modification of M. Goux's system, that of lining the receptacle with dry manufacturing refuse. Each closet in the town receives at least, twice a week, a tub which is lined with any cheap absorbent—that which is found most useful and handy is the spent dyewoods of the place, as fustic, &c., which are first dried by artificial heat and then rammed into a tub by means of a central core which gives it an uniform lining. At the time when the fresh tub is supplied the old one with its contents is taken away, and carried to the manure yard belonging to the Corporation. About two tons of material are thus furnished by each closet annually, and it readily sells at the contract price of 5s. 6d. per ton. According to Dr. Syson, the system is both manageable and effective ; and it not only utilizes the excreta of the population, but it also enables the local authorities to remove it quickly and thoroughly. In time of epidemic disease, it likewise enables them to disinfect the excreta, and so to prevent the spread of certain pythogenic disorders. The same plan has been tried experimentally at Rochdale, but not successfully, and it has, therefore, been abandoned ; although the agent of M. Goux, the Messrs. Holt and Glazier of Rochdale, speak of it as a very manageable and

profitable method of removing fæces, &c. They say that it costs 35s. to convert a midden closet into the new form, and that a set of tubs for the closet will cost 10s., making a total of 45s. for the change. In working the process they calculate, from their experience at Rochdale and Salford, that two men and one horse will remove 600 tubs per week, each tub containing on an average 84 lbs. of excremental matter, &c. This gives a total of twenty-two and a-half tons a week, which, at a working cost of £3 a week for the men and horse, averages 2s. 9d. a ton, the material being worth at least 5s. or 6s. a ton, as it is received from the privies, although, when manipulated on the plan advocated by M. Goux, they say it is worth £2 a ton.

In the old parts of Edinburgh, where there are no closets in the houses of the poor, the contents of the chamber vessels are mixed with the ashes and put into tubs for the scavengers to remove daily; but there are also public closets, which are provided with moveable cans that are changed daily. About fifty of these latrines, with from eight to forty separate seats or compartments to each, are provided in the old town. They are situated at a rather higher level than the street, so that the proper receptacles may be easily placed beneath them. These receptacles are very much like the tin cans which are used for bringing milk by rail to London. A separate can is placed under each seat so as to receive all the discharge, and the scavengers remove the cans daily, and replace them with fresh one's before the town is awake. They are carried to the depots, which are outside the city, but near to a railway station, and their contents are mixed with ashes and street-sweepings. About 50,000 tons are thus collected and disposed of yearly, the return being about £7,000, against the charge of £13,000 for scavengering the city. The same method of collecting the excreta of the population is fast coming into use in Glasgow, portable vessels being placed beneath the seats of the closets. At Rochdale, also, with a population of about 46,000 persons, and about 4,000

midden closets, the Corporation have adopted the plan of collecting the excreta in similar moveable receptacles, the ashes and other house refuse being kept apart in separate tubs. The receptacles are rudely constructed of old paraffin casks cut in half, and provided with handles. They are changed once, twice, or thrice a week, according to circumstances, and when they are removed from the privy they are immediately secured with a tight-fitting cover to prevent the escape of offensive effluvium. At present there are only about 500 closets fitted with these receptacles, and they yield about 24 tons of excreta per week. These, with 10 tons of ashes previously placed in them, are converted into 18 tons of manure, which sells at 15s. a ton, although it is thought to be worth at least 30s. a ton. The total cost of working the whole of the 4,000 closets in this manner would, according to Mr. Alderman Taylor, be about £12 a week, and, in his opinion, the manure at 15s. a ton, would be worth £13 10s. a week; besides which there would be the additional value of the ashes, &c., which are collected separately.

But although a large quantity of excrement is thus collected in the chief towns of Lancashire, and, therefore, diverted from the rivers and water courses of the district, yet, according to the Rivers' Pollution Commissioners, it has had no appreciable effect on the conditions of the outfall streams. They say, in fact, that the sewage of Manchester, Liverpool, Salford, Macclesfield, Bolton, Bury, Preston, Blackburn, Wigan, and other midden towns of Lancashire, is but little better than that of places where all the excreta are discharged into the sewers; and in illustration of this they give the chemical composition of thirty-seven samples of sewage from fifteen midden towns, &c., and of fifty samples of sewage from seventeen places where water-closets are used, and the following are the maximum, minimum, and average results per imperial gallon :

	Constituents per gallon.	Maximum.	Minimum.	Average.
		Grains.	Grains.	Grains.
Sewage of midden towns.	*Matters in solution* .	293·72	21·77	57·68
	Organic and other Nitrogen . .	9·17	1·11	4·52
	Chlorine . .	15·05	4·55	8·08
	Matters in suspension	92·26	6·02	27·38
	Organic . . .	36·48	3·12	14·91
	Mineral . . .	55·78	2·90	13·47
Sewage of water-closet towns.	*Matters in solution*	82·46	28·84	50·54
	Organic and other nitrogen . .	17·03	1·66	5·41
	Chlorine . .	15 05	3·01	7·46
	Matters in suspension	163·91	3·46	31·29
	Organic . . .	35·95	2·87	14·36
	Mineral . . .	127·96	0·59	16·93

From which it would seem that although the average amount of suspended matter in the midden sewage is a little less than that of water-closet sewage (in the proportion of 27·38 grains to 31·29), yet the dissolved matters are actually more (in the proportion of 57·68 to 50·54); and notwithstanding that the quantity of sewage from a water-closet town is considerably laiger than that from a midden town, yet, judging from the proportions of chlorine in the two cases, representing, as it generally does, the quantity of common salt in the urine, the Commissioners conclude that, for equal volumes of sewage, there have been 1·154 persons contributing to it, in the case of the midden towns, and 1·064 in the other. The inconsistency of these conclusions is demonstra ted by the very facts which the Commissioners have themselves published, as to the quantity of night-soil collected annually

and sold for manure in the several midden towns alluded to, all of which is so much matter kept out of the sewers. It ranges from 1,200 tons a year at Clithero, with a population of 7,000 persons, to 138,777 tons at Liverpool, with a population of 500,676—the average amount at sixteen places, with an average population at each place of 93,785 persons, being 25,561 tons per annum; which is more than six times the total quantity of suspended matters in the entire sewage of the several places, supposing them to have been water-closet towns, yielding an average of 60 gallons of sewage per head per diem, and that the sewage contained 31·29 grains (the Commissioners' proportion) of suspended matters per gallon. It is hardly possible to imagine a more extravagant illustration of the way in which opinions created by an impulsive bias may be made to over-ride the actual facts of an inquiry.

On the Continent, the excreta of the population is collected in water-tight pits, or moveable receptacles, the emptying of which is performed by a contractor in the service of the municipality; and there are many ingenious contrivances for the removal of the night-soil without occasioning offence. At Milan and Paris, for example, the materials are forced by means of atmospheric pressure through tubes in connexion with the cess-pool and an exhausted tank or barrel. The tanks are in the form of waggons, and having been exhausted of atmospheric air at the works, they are sent to the place from which the cess-pool matter is to be removed; and after connecting a flexible hose with the tank and cess-pool, the valve-tap is opened, when the atmospheric pressure forces the night-soil into the exhausted tank, without permitting any escape of offensive effluvium. A like contrivance has been patented in this country by Mr. James John Shedlock (1864); and the arrangements of Captain Leirmur for this purpose are somewhat similar. He proposes that a tank should be conveniently placed in the middle of a street, so as to receive the discharges from

fifteen or twenty houses, and that when full it should be emptied by means of exhausted barrels. Mr. Dyer, of Melbourne, proposes that the closets should be at the top of the houses, and that the excreta should be conveyed by soil-pipes, like rain-water pipes, to close tanks conveniently placed below. But none of these contrivances are easy to manage, and they require such constant attention to ensure their safety, as to be practically unavailable, except in particular cases. The disposal of the night-soil is also difficult, although at Milan and Paris it is converted into manure, but the process is offensive and hardly remunerative. At Paris, for example, the material is collected by the contractor appointed for the purpose, who charges a fixed price, arranged by the municipality, for the work. The material is first sent to Villette, and then to Bondy, where it is converted into *poudrette*, and ammoniacal salts. The buildings and works at Villette and Bondy were erected by the city of Paris at a large cost; and the contractor who uses them pays a fixed price of 1 franc a cubic metre for the solid matter, and 1¼ franc per cubic metre for the liquid. Every 10,000 cubic metres of the raw material, costing about 11,000 francs, yield about 545 cubic metres of poudrette (worth about 25,888 francs), and 704 kilos, of ammoniacal salts (worth about 7,744 francs), and 125 cubic metres of liquid manure (worth about 125 francs). So that, at a cost of 11,000 francs for raw material, the products realise 33,757 francs, or rather more than 300 per cent.; but for all this, the return is not remunerative, for the average cost of removing the excreta from Paris is about £5 per house per annum, and the nuisance of the manufacture is frightful. The same is the case at Milan, as it also was at Hyde, near Manchester, when, a few years ago, in carrying out the "Eureka system," night-soil was converted into manure. Mixed with earth, however, as is the practice in China, it is not so offensive, and it forms a convenient and merchantable compost.

COMPOSITION OF

HUMAN EXCRETA, AND OF SEWAGE,

AND QUANTITIES OF EACH YIELDED PER DIEM BY THE POPULATION.

Having described in detail the various processes in operation at different places for the disposal of sewage and human excreta, and having also ascertained what are the results thereof, we are now able to discuss the question of the most safe, easy, and profitable means of utilising them. Preliminary to this, however, it is obviously of great importance that we should have correct notions of the composition of sewage and human excrement; and to this end we will inquire into the results of the analysis of fæces, urine, sewage, &c.

The investigations of Messrs. Way, Lawes, and Playfair, in this country, and of MM. Liebig, Simon, Wolf, Lehmann, Fleitmann, and others, on the continent, have sufficiently explored the subject to enable us to construct the following table, which represents, not merely the average proportions of solid and liquid matters discharged daily from the human body, but also the proportions of the chief constituents of urine and fæces in the case of children and adults of both sexes.

AVERAGE WEIGHT, IN AVOIRDUPOIS OUNCES, OF THE CHIEF CONSTITUENTS OF URINE AND FÆCES PASSED BY CHILDREN AND ADULTS IN TWENTY-FOUR HOURS.

Chief constituents.	Males.		Females.		Average at all ages.
	Boys.	Men.	Girls.	Women.	
URINE.	oz.	oz.	oz.	oz.	oz.
Fresh state	19·875	48·490	16·881	42·157	31·851
Dry matters	0·969	2·197	0·750	1·588	1·376
Organic matters	0·677	1·720	0·574	1·216	1·072
Nitrogen	0·166	0·481	0·161	0·326	0·284
Mineral matters	0·292	0·477	0·176	0·372	0·332
Phosphoric acid	0·035	0·069	0·024	0·049	0·044
Potash	0·040	0·078	0·027	0·055	0·050
FÆCES.					
Fresh state	3·421	5·240	1·061	1·414	2·784
Dry matters	0·879	1·112	0·282	0·376	0·662
Organic matters	0·762	0·939	0·244	0·325	0·567
Nitrogen	0·049	0·062	0·016	0·022	0·037
Mineral matters	0·117	0·173	0·038	0·051	0·095
Phosphoric acid	0·039	0·062	0·013	0·018	0·033
Potash	0·014	0·023	0·004	0·006	0·012

So that the range in the daily proportion of liquid and solid excrement from children and adults of different sexes is considerable, as from 17·94 ounces, in the case of girls, to 53·73 ounces in that of men—the dry solid matters in

the two cases being 1·03 oz. and 3·31 oz. In order, therefore, to estimate, approximately, the total amount of excrementitious matters contributed by a mixed population of different sexes and ages, we must take the normal proportions of them as they occur in a town population of— say 10,000 individuals ; and then the following will be the daily quantities contributed in each case :—

AMOUNTS OF SOLID AND LIQUID MATTERS CONTRIBUTED DAILY BY A TOWN POPULATION OF 10,000 PERSONS—CONSISTING OF 1,644 BOYS, 3,020 MEN, 1,662 GIRLS, AND 3,674 WOMEN.

Chief constituents.	Males.		Females.		Total at all ages.
	Boys.	Men.	Girls.	Women.	
URINE.	lbs.	lbs.	lbs.	lbs.	lbs.
Fresh state . . .	2073·2	9152·5	1753·6	9680·3	22659·6
Dry matters . . .	99·6	414·7	77·9	364·6	956·8
Organic matters . . .	69·5	324·6	59·6	279·2	732·9
Nitrogen . . .	17·1	90·8	16·7	74·9	199·5
Mineral matters . . .	30·0	90·0	18·3	85·3	223·9
Phosphoric acid . .	3·6	13·0	2·5	10·6	29·7
Potash . . .	4·1	14·7	2·8	12·7	34·3
FÆCES.					
Fresh state . . .	351·5	989·1	110·2	324·7	1775·5
Dry matters . . .	90·3	209·9	29·3	86·3	415·8
Organic matters . . .	78·3	177·2	25·3	74·6	355·4
Nitrogen . . .	5·0	11·7	1·6	5·0	23·2
Mineral matters . . .	12·0	32·6	3·9	11·7	60·2
Phosphoric acid . .	4·0	11·7	1·3	4·1	21·1
Potash . . .	1·4	4·3	0·4	1·4	7·5

From which it appears that every 1,000 persons in a mixed town population contributes 2,266 lbs. (avoirdupois) of urine, and 177·5 lbs. of fæces per diem, the dry solid matters of which amount to 137·2 lbs.; and they contain 108·8 lbs. of organic matter (with 22·3 lbs. of nitrogen) and 28·4 lbs. of mineral matters (with 5·1 lbs. of phosphoric acid, and 4·2 lbs. of potash). The average amount per head of the population is 39·1 oz. of moist material, containing 2·2 oz. of dry solid matter, of which about 291 grs. are insoluble in water.

But these are not the only matters contributed to the sewage of a town, for it also receives the fluid refuse of every branch of industry, as the filth of kitchens, laundries, and dye-houses, the drainings from stables, slaughter-houses, and markets, the liquid impurities of trades and manufactures, and the washings of the public thoroughfares. These, with the excreta of the population, and a large volume of domestic and sub-soil water, make the complex liquid which forms the sewage of a town, and which varies in its composition, with the habits of the people, the season of the year, and even the hour of the day. It is, therefore, difficult to arrive at a very absolute conclusion respecting the average composition of sewage. Perhaps, however, the sewage of this metropolis may be taken as a very near approximation to a normal standard; and we submit the following as the average results of a great number of analyses by Dr. Letheby, of the sewage discharged at all hours, and at all seasons, from the outfalls of ten of the large City sewers, whose ordinary rate of flow, at mid-day, is about 3,490 gallons per minute.

CHIEF CONSTITUENTS OF A GALLON OF LONDON SEWAGE.

Chief constituents.	Day sewage.	Night sewage.	Storm sewage.
	Grains.	Grains.	Grains.
Soluble matters . .	55·74	65·09	70·26
Organic matters . .	15·08	7·42	14·75
Nitrogen . .	5·44	5·19	7·26
Mineral matters . .	40·66	57·67	55·71
Phosphoric acid .	0·85	0·69	1·03
Potash . . .	1·21	1·15	1·61
Suspended matters . .	38·15	13·99	31·88
Organic matters . .	16·11	7·48	17·55
Nitrogen . .	0·78	0·29	0·67
Mineral matters . .	22·04	6·51	14·33
Phosphoric acid .	0·89	0·64	0·98
Potash . . .	0 08	0·04	0·16

If mid-day sewage, therefore, be taken as representing the average composition of London sewage, it will be seen that it contains about 94 grains of solid matter per gallon—55·7 of which are in solution, and 38·2 in suspension. The organic matter amounts to 31·2 grains per gallon—of which 15·1 are dissolved and 16·1 suspended. The total amount of nitrogen in the sewage is 6·22 grains per gallon, and of this 5·44 grains are dissolved and 0·78 in suspension. Of the mineral matters, amounting to 62·7 grains per gallon, 1·74 are phosphoric acid, and 1·29 potash.

These proportions of the most important constituents of sewage are not very different from the results obtained by Dr. Hofmann and Mr. Witt in their enquiries in 1857 into the mean composition of London sewage. Their samples were obtained from the Savoy-street sewer, because the Government referees considered that it furnished the best specimen of normal London sewage; and they were taken hourly during the twenty-four hours, and mixed, so as to

produce a fair average sample. This yielded 30·7 grains of organic matter per gallon, 6·76 grains of nitrogen, 1·85 of phosphoric acid, and 1·03 of potash—quantities which are very similar to those obtained by Dr. Letheby. The analyses, also, of the Rugby sewage, made by Mr. Way in 1861, 1862, and 1863, for the Royal Commission appointed to inquire into the best mode of distributing the sewage of towns, gave almost the same result; for it was found, as a mean of 93 analyses, that a gallon of sewage contained 92·5 grains of solid matter—29 of which were organic, and 63·5 mineral. The nitrogen, in the complete analyses, amounted to 6·18 grains per gallon; the phosphoric acid to 1·68 grains; and the potash to 2·81 grains. Dr. Voelcker's estimate of the average composition of sewage is a little too low; for he says a gallon of sewage contains 70 grains of solid matter (or one part in a thousand), and of these 20 grains are organic (yielding 5·67 grains nitrogen, or 7 ammonia), and 30 are mineral (yielding 1 grain phosphoric acid, and nearly 3 grains of potash). These results are shown in a tabular form on page 138.

The amount of sewage contributed daily by the inhabitants of London were, at the time of the analyses, about six cubic feet, or nearly 37·5 gallons per head of the population; and of this about 80 per cent. was represented by the water-supply. It is easy, therefore, to distribute the principal constituents of sewage under the head of human excreta, and other fluid refuse; for to take the sewage of 1,000 persons in a town population, it may be said that the following are, approximately, the chief sources of the several impurities contained in it.

WEIGHT IN POUNDS (AVOIRDUPOIS) OF THE CHIEF CONSTITUENTS OF THE SEWAGE DAILY FURNISHED BY EVERY 1,000 PERSONS OF A TOWN POPULATION, AND THE SOURCES THEREOF.

Chief constituents of 3,750 gallons of sewage.	From excreta.	From other refuse.	Total.
	lbs.	lbs.	lbs.
Soluble matters . .	95·7	202·9	298·6
Organic matters . .	73·3	7·5	80·8
Nitrogen . .	20·0	9·1	29·1
Mineral matters . .	22·4	195·4	217·8
Phosphoric acid .	3·0	1·6	4·6
Potash . . .	3·4	3·1	6·5
Suspended matters . .	41·6	162·8	204·4
Organic matters . .	35 6	50·7	86·3
Nitrogen . .	2·3	1·9	4·2
Mineral matters . .	6·0	112·1	118·1
Phosphoric acid .	2·1	2·7	4·8
Potash . . .	0·8	—	0·4

It is very probable, looking at the relatively large amount of nitrogen in the matters derived from other refuse than human excreta, that the estimated quantity of nitrogen in the latter is a little too small; or it may be that the nitrogen of the mid-day sewage, which is here taken for comparison, is somewhat in excess of the average; or perhaps both these causes are concerned in yielding so large a quantity as 9 lbs. of nitrogen to 7·5 of organic matter. The Commissioners appointed to inquire into the best mode of distributing sewage, say, in their third report, that after a very exhaustive inquiry they find that 12·6 lbs. of ammonia is the amount annually yielded by each average individual of a town population. This would give a total of 28·43 lbs. of nitrogen daily by 1,000 persons, instead of 22·3 as we have estimated. Broadly, however, it may be said that the 3,750 gallons of sewage

contributed daily by every 1,000 persons of a town population, contain about 167 lbs. of organic matter, 33·3 lbs. of nitrogen, 9·4 lbs. of phosphoric acid, and 6·9 of potash; and of these nearly half the organic matter, seven-eighths of the nitrogen, about half of the phosphoric acid, and nearly all the potash are in solution. The relation, therefore, of the most important constituents of sewage are as follows : –every 10 parts of organic matter represent 2 parts of nitrogen ; and every 10 parts of nitrogen are associated with 2·82 parts of phosphoric acid, and 2·07 parts of potash

Chief Constituents of a Gallon of Sewage.

Authorities.	Organic Matter.	Nitrogen.	Phosphoric Acid.	Potash.
	Grs.	Grs.	Grs.	Grs.
Letheby - - - -	31·19	6 22	1·74	1·29
Hofmann and Witt - -	30·70	6·76	1·85	1·03
Way - - - -	29·00	6·18	1·68	2·81
Voelcker - - -	20·00	5·67	1·00	3·00
Mean - - - -	27·72	6·21	1·57	2·03

The average amount of solid matter per gallon is 89·81 grains, of which 27·72 are organic and 62·09 mineral.

COMMERCIAL AND AGRICULTURAL

VALUE OF SEWAGE AND NIGHT-SOIL.

Like all complex manures, the excremental matters of a town population have two very different values—one being theoretical and the other practical. The theoretical value of night-soil, for example, supposing it to consist of all the excreta, liquid as well as solid, of a population, and supposing also that the several constituents are estimated at their market price in a concentrated form, is 15s. 8d. a ton; whereas the price realised in commerce is never more than 3s. a ton. Urine alone, at the theoretical value of its constituents, is worth 15s. 10d. a ton, and fæces £1 7s. 6d.; but who ever heard of either of them fetching more than a tenth part of these sums. At Nottingham there is a much frequented public urinal with fourteen compartments, and the money realised by the sale of the urine to the farmers is 20s. per annum; and with respect to cesspool matter, it was regularly sold in this Metropolis for 2s. a ton, delivered into barges on the river or canal. In Paris, at the present time, the solid portion of the City cesspools is disposed of by the Municipality to a company at 10d. per cubic metre, and the liquid at 1s.—the cubic metre being over a ton in weight. At Manchester, Salford, Edinburgh, Leeds, and other places, where the midden system is in operation, the soil from the privies is sold with other refuse at from 1s. to 1s. 6d. per ton. Liebig says that in the year 1858 the contents of the cesspool in the fortress of Rastadt, in the

Grand Duchy of Baden, where there were 8,000 soldiers, was sold for 8,155 florins (£815), the contents being the accumulation of one year. Now, as the average yearly produce of a male adult is about 1,193 lbs. of solid and liquid matter, the 8,000 soldiers must have contributed about 4,260 tons of excremental matter; and as these realised £815, the return was at the rate of 3s. 10d. per ton, or 2s. per head per annum—although the theoretical value of the excrements of a male adult is 18s. 6d. per ton, or 10s. 1d. per head per annum. In Holland and Belgium the computed value of the excrement of a town population is from 20s. to 30s. per head per annum, but the price actually realised is only about 1s. a head. The same is the case with other kinds of manure, when they are mixed with large bulks of inert or worthless matter. Rotten stable dung, for example, as well as fresh farm yard manure is worth, according to the theoretical value of its constituents, from 13s. 6d. to 14s. per ton, whereas in fact it only realises from 3s. to 5s. a ton.

As regards the commercial and agricultural value of sewage the discrepancies are still more remarkable. In the evidence before the Select Committee of the House of Commons in 1862, the value of it was variously stated at from ½d. to 9d. per ton. The Earl of Essex thought it should be supplied to the farmer at rather less than a penny per ton; but Messrs. Lawes, Way and Morton valued it at 1d.; Liebig and Voelcker at 1¾d.; Mechi, Hofmann, and Witt at 2d. In reality, however, no one will buy it at any price, unless he has the opportunity of using it when he pleases, and then he will pay at the rate of from 5s. to 6s. per acre for it, provided the local authority will deliver it upon his land in the quantity required, and whenever required. A farmer would be glad to take water at this price, for there are seasons when it is desirable to have an abundance of moisture to help forward the young crops, and especially grass upon meadow land. Even in the case of the Craigentinny meadows at Edinburgh, where the yield of grass is enor-

mous, the sewage is not used continuously, but is diverted from the land to the sea when it is not wanted; and although they realise in good seasons from £20 to £30 worth of green produce per acre, yet the quantity of sewage used is not less than from 10,000 to 13,000 tons an acre per annum, which at an average price of £25 for the produce, is less than a halfpenny a ton, irrespective of rent and farming expenses. At 1d. per ton the sewage would cost £62 10s. a year. In reality, however, it costs nothing, and the same is the case at Worthing, Rugby, Croydon, Carlisle, Aldershot, and elsewhere. So disinclined, in fact, are the farmers to take sewage at any price, that local authorities are obliged to appropriate land on their own account, when, for sanitary purposes, they resort to irrigation. This apparent obstinacy on the part of farmers is attributed by scribes and fluent talkers to ignorance, and to old fashioned prejudices. It is owing, says the writer of a recent leader in the *Lancet*, to "his pig-head reverence for the practice of his forefather, and his ignorant belief in his own experience;" but in answer to this we have the fact that farmers are quite able and willing to appreciate the advantage of any description of agricultural novelty which is really valuable; and the employment of guano, of superphosphate, of alkaline nitrates, and of ammoniacal and other portable manures, as well as the adoption of all kinds of newly invented agricultural implements, during the last thirty years, and the expenditure of large sums of money in subsoil drainage, are sufficient proofs that the farming world is quite ready to avail itself of every useful invention of art, and suggestion of science. It is abundantly evident, indeed, that there is some other obstacle to the use of sewage as a manure, than the "pig-headed reverence of the farmer for the practice of his forefathers;" for if sewage had possessed but half the value which some loud talking people are ever proclaiming, it would long since have been the subject of successful speculation, and hav formed the basis of many a flourishing joint-stock com-

pany. There would have been no occasion for the thousands of blue-books, which have been distributed at the public expense, with the authority of the Board of Health, of Royal Commissions, and of Parliamentary Commitees —all worked by the same influence; for the farmer, as well as the local authority, would long since have established the value of sewage, if it had any, and would have realized its worth.

The history of this attractive, but groundless, theory of the agricultural value of sewage is worth recording, and we will epitomise the account of it as given in a very able pamphlet on "The Agricultural Value of the Sewage of London." The theory originated with Mr. Smith, of Deanston, who was a cotton spinner, and had used the privy soil of his factory with some advantage in growing all sorts of crops; although it seems his wheat crops were infinitely richer in straw than in grain. His pursuits as an experimental farmer and cotton spinner not proving successful, perhaps from his extraordinary taste for experiments, he became a Commissioner under the first Board of Health, created by Mr. Edwin Chadwick, and in that capacity he visited Edinburgh in 1844. There he saw, in active operation, the sewage meadows which had been established many years, and which yielded, as they still do, enormous crops of rank grass, available only for dairy purposes. It immediately occurred to Mr. Smith's ingenious mind, that the sewage of all the towns of England, especially those which were sewered under the control of the Board of Health, and which were fast getting into difficulties from legal prosecutions for fouling the neighbouring water courses, might be utilised for agricultural purposes. He thereupon proposed to irrigate grass land on the water-meadow system, and when this could not be done, to convey it by means of pipes to the most convenient parts of the farm, and to distribute it under a pressure of 150 feet by means of hose and jet. This capital idea was at once adopted by Mr. Edwin Chadwick, who carried the theory still fur-

ther, declaring that liquid manure was, *at all times*, preferable to solid manure, and that it was suitable for all crops and for all soils. His theory with detailed instructions for the arrangement of pipes, &c., was circulated extensively, with all the authority and influence of the Board of Health; and it was one of the instructions of the Board that every system of sewers should be brought to one outfall, with the view of applying the sewage to agricultural purposes. Such an authoritative announcement, that town sewage contained an abundance of rich manurial elements, and could be profitably used in agriculture, commanded, as well it might, a good deal of attention; and men of fortune of an enterprising turn, with a taste for agriculture, accepted the tempting theory—that liquid manure was superior to, and could supersede all solid manures; and a number of farms in England and Wales were underlaid with pipes, and provided with steam engines and pumps and hose at vast expense. In Scotland, too, very perfect examples were provided, one by Mr. Telfer, another by Mr. Kennedy, which for a few years were continually cited as instances of the success of liquid manure applied by jet and hose with steam power. Both of these gentlemen grew extraordinary and repeated crops of Italian rye grass, which were the subjects of sensational speeches at farmers' meetings by Mr. Mechi and others. Mr. Mechi himself piped his farm, provided it with a steam engine, and announced his intention of feeding his live stock—cattle, sheep, and pigs—under cover upon boards without straw, of reducing his straw to chaff for the consumption of his beasts, and using all the manure thus made in a liquid form. Tiptree, in fact, was to dispense with solid manure and top-dressing for all its crops, and was to rely for fertility on the supply of the jet and hose. The hose and jet farm of Mr. Neilson, a Liverpool merchant, was likewise a constant subject of eulogy by the Board of Health; and Mr. Littledale, another Liverpool merchant, fitted up a dairy farm on the same plan. In Norfolk, Mr. Chamber-

laine, a wealthy retired tradesman from Norwich, purchased an estate, and laid it out at extraordinary expense, under Mr. Mechi's advice, with steam power and pipes; and there were other establishments which it is not worth while to name—none of them being supplied with town sewage, but all, with one exception, working after the plan recommended by the Board of Health, namely by steam power, and not by gravitation, and all attempting to cultivate all crops with liquid manure. The exception was the Rev. Mr. Huxtable, who once made as much sensation as Mr. Mechi by undertaking to teach plain farmers their business, and all the mysteries of agricultural chemistry. Mr. Huxtable employed gravitation to distribute liquid manure; but it may safely be asserted that not one of these liquid manure farms paid a rent. Mr. Neilson became a drainage inspector and gave up farming; Mr. Telfer failed; Mr. Kennedy, after sinking an enormous sum on Myremill, disappeared from the sensational world of agriculture; Mr. Huxtable, most extraordinary of all, not only found out, but acknowledged his mistake, and gave up the liquid system, and his idea of dispensing with solid manure, and limited his operations to a few acres of home farm. Mr. Chamberlaine's attempt at model farming proved disastrous, and eventually the pipes were taken up and sold for old iron. Mr. Litttledale confined his operations to growing rye grass for his fancy dairy, but grew corn with solid manure and top dressings of guano, and never pretended to make a profit. As for Mr. Mechi, at some mysterious date, he took to the ways of the Norfolk, and other retrograde farmers, whom he had often denounced, and used his stock to tread his straw into manure. He grew his mangolds with liberal loads of solid long-straw manure, and dry superphosphate, and had his wheat to follow—his costly liquid manure apparatus being used as a gigantic watering-pot.

After twenty years of agitation in this manner, with all the influence of the Board of Health, and the apparently tempting results at Edinburgh, there were but six places

in England, in 1864, where town sewage was attempted to be utilised by irrigation, and those were—Rugby, Croydon, Carlisle, Alnwick, Malvern, Tavistock, and Watford. The farm at Rugby was laid out in the most approved fashion, and was managed by a very enthusiastic gentleman, Mr. Campbell, who had studied the operations at Edinburgh; but after eleven years of unsuccessful experience he abandoned it, and said in a letter to the *Times* of the 18th of November, 1864, that he had used the sewage of Rugby ever since the formation of the works, both upon his own land, and upon that of others, to the extent of 190 acres, but he was sorry to say that in a pecuniary point of view it had been altogether unremunerative. After this it was taken in hand by Mr. Congreve and Mr. Walker, two other enthusiastic gentlemen, but they also abandoned it, and now it is in the possession of the local authorities, who work it for sanitary purposes. At Croydon, the pressure of legal proceedings for nuisance created by the discharge of sewage into the river Wandle, forced the local authorities, through the suggestive teachings of the Board of Health, to adopt the irrigation system, and until recently the farm has been rented by Mr. Marriage, but for some reason or another he has abandoned it; and although attempts are being made to form a joint-stock company to work it, the prospects are not hopeful. Almost everywhere, in fact, the system has failed, in both an agricultural and commercial point of view, and hence there are very subdued and modified opinions of the value of sewage farming by those who were once its most earnest advocates. Mr. Rawlinson, for example, the Board of Health champion of irrigation, has apparently come to the conclusion that it will not pay if sewage has to be paid for; for in his evidence before the Parliamentary Committee, in 1864, he said, in speaking of Worthing, where he was part proprietor of a sewage farm, that "they (the local authorities) had acted with wisdom, for they charge nothing for the sewage; if they had charged anything there would have been no experi-

ments; they give the sewage, and they lift it upon the land." He also said, in speaking of the London sewage, that "if any company is induced to enter into the speculation of applying the sewage of London, and agrees to pay the sums I have heard named, they will be in bankruptcy very shortly." He therefore evidently looks on sewage as a thing to be got rid of, and ought to be given away by the local authorities, for farmers cannot afford to pay anything for it.

It is manifest from all this that the true value of sewage has been determined by actual experiment and fair investigation, and that the objections to its use do not arise from what the editor of the *Lancet* calls the farmer's "ignorant belief in his own experience," but from a very careful inquiry into its merits, and from the total failure of practical results. On this head we have valuable testimony by Dr. Voelcker, who is one of the highest authorities on this subject, and who says that nowhere have experiments on agricultural subjects been more extensively tried than in England; and, seeing the great success of irrigation with liquid manure in Flanders, where the soil is almost barren, men have thought that the system ought to be equally successful in this country, and have perseveringly tried it. Sometimes the results have been advantageous, but generally they have been a complete failure, and have been abandoned. "A principle," he says, "like that which informs us that fertilizing matters produce their maximum effect in liquid form, may be true in the abstract, or with reference to particular kinds of plants, or in certain climates, or with reference to soils of a particular character, but in other climates or other soils there may be operating causes which render it by no means advisable to administer manuring matters in a state of solution."

The great fallacy which is everywhere present in the theoretical estimate of the value of sewage is, that its constituents are supposed to be isolated in a solid and portable form, as is the case with guano, superphosphate,

and ammoniacal manures. In fact, the almost invariable remark is that, *if extracted and dried*, the manure elements of sewage, &c., would be worth so and so, but this is the whole difficulty, and it is by disregarding it that such enormous discrepancies in the real and theoretical values of sewage and night-soil exist. The dry, solid matter of urine is estimated at £18 14s. 1d. a ton; those of fresh fæces at £5 17s. 7d. a ton; and the dry matter of the excreta (solid and liquid) of a mixed population at £14 16s. 4d. a ton. In this manner, and from these data, an estimate is formed of the yearly value of the excreta of an average individual, and it ranges from 6s. 6d. a head, to 20s. Mr. Latham computes it at from 6s. 6d. to 8s. 6d. per head per annum of the general population, and at 10s. 6d. for an adult; Dr. Anderson of Glasgow, at 8s. (viz., 6s. 6d. for the urine, and 1s. 6d. for the fæces). The Royal Commissioners on Sewage (Mr. Lawes and Mr. Way) value it at 8s. 5¾d.; Dr. Hoffmann and Mr. Witt at 11s. 9¼d. (10s. ½d. being for the urine, and 1s. 8¾d. for the fæces); Dr. Hawksley at 16s.; and Dr. Thudichum at 20s. per head, per annum (10s. 3½d. being for the urine, and the rest for the fæces); and with regard to sewage, the estimate ranges from 1d. to 2d. per ton of 220 gallons.

Again, when compared with other forms of manure, the agricultural value of sewage and night-soil has been variously computed. Macaire and Marcet, for example, say that 1 lb. of human excrement is equal in fertilizing power to 13 lbs. of horse-dung, or 6 lbs. of cow-dung. Mr. Mechi considers that the excreta (liquid and solid) of each person are of the same manurial value, per annum, as the droppings of one sheep, and Mr. Bailey Denton considers them to be equal to a load of good farm-yard manure, and to be worth 6s. Dr. Voelcker states that the annual secretions of one average person is about equal to 75 lbs. of Peruvian guano, which will yield about 3·2 bushels of grain, worth £1. Boussingault says that the excreta of an adult man (for a year) contains enough nitrogen (16·41 lbs.) to furnish the nitrogen of 800 lbs. of wheat, rye, or oats, or 900 lbs. of barley, of the value of £5.

With regard to sewage, Liebig says that 828 tons of London sewage contains as much ammonia as a ton of Peruvian guano, but that it is deficient in phosphoric acid, and requires superphosphate to bring it up to a proper manurial standard. The Commissioners appointed to enquire into the best means of distributing the sewage of towns, say, from an average of ninety-three analyses of Rugby Sewage, during the years 1861, 1862, and 1863, that 1,000 tons of it contain the nitrogen of the mixed excrements of between seventeen and eighteen persons of both sexes, at all ages, for a year ; and that they are equal to between eleven and twelve cwt. of Peruvian guano. Dr. Hofmann and Dr. Frankland are of opinion that 1,250 tons of London sewage contain an amount of fertilizing matter which, if extracted and dried, would exactly correspond with the amount found in one ton of Peruvian guano ; and Liebig says that experiments made in six different parts of Saxony have shown that each cwt. of Peruvian guano produces, when properly put upon the land, 150 lbs. of wheat, 400 lbs. of potatoes, and 280 lbs. of clover more than the land would produce without it.

From such estimates as these, regardless of the quantity of worthless matter in sewage, the most extravagant notions have been entertained of its value, as that the sewage of this metropolis is worth from one and a-half to ten millions, sterling, annually. Messrs. Hofmann and Witt, for example, estimate it at £3,796, daily, or £1,385,500, annually. Mr. Mechi puts it down at two millions, and upwards ; and Mr. Brady and Lord Robert Montague, the two Chairmen of the Parliamentary Committees, appointed to enquire into the utilization of the sewage of towns, report it to be equal in manurial value to 212,842 tons of Peruvian guano, which at £13 12s. 6d. per ton, is worth £2,899,972. But these are the dreams of enthusiasts, although, perhaps, they may be made intelligible to more practical men by the following table, which represents the composition and estimated value of the solid matters of sewage and night-soil in their natural

state, and also when brought into a dry and portable condition, like reasonably good manure; supposing they have lost nothing by drying, and that ammonia is worth 7d. a lb.; soluble phosphoric acid, 4d. a lb.; insoluble acid, 2d. a lb.; and potash, 3d. a lb, which are very nearly the present market values of these substances in a concentrated form :—

Constituents per Ton.	Ammonia.	Phosphoric Acid.		Potash.	Estimated Value per Ton.
		Soluble.	Insoluble.		
	lbs.	lbs.	lbs.	lbs.	£ s. d.
In natural state—					
Urine	23·94	2·94	—	3·39	0 15 10
Fæces	35·45	—	26·62	9·46	1 7 6
Mixed excreta of population...	23·13	2·70	1·93	3·83	0 15 8
Dry solid matter of—					
Urine	567·14	69·53	—	80·32	18 14 1
Fæces	151·77	—	113·67	40·40	5 17 7
Mixed excreta of population...	441·31	48·47	34·43	68·21	14 16 4
Sewage	172·10	22·89	10·19	48·20	6 3 2
In natural state—					
Rotten farm-yard dung ...	16·00	3·92	5·77	10·00	0 14 1
Fresh do. do. ...	15·00	3·00	3·92	12·50	0 13 6
Peruvian guano	381·80	67·00	201·00	13·50	14 1 4
1,000 tons of average sewage*	219·37	27·61	24·20	50·65	0 0 1¾

* The composition of sewage is the average of the analyses of Liebig, Hofmann, Witt, Voelcker, Letheby, and the Royal Sewage Commissioners.

In all these cases, as we have said, the estimates are formed upon the supposition that the whole of the nitrogen has been retained by chemical means during the process of consolidation ; for, if this has not been provided for, the nitrogen which exists as ammonia or carbonate of ammonia will have been lost in the evaporation, and the phosphoric acid will have combined with lime and have become insoluble. This is shown in the following Table, which gives the composition and money value of the solid matters of fæces and sewage, according as they are estimated from the constituents of these matters when in a natural state or when artificially dried :—

Constituents per ton.	Nitrogen.	Phosphc Acid.	Potash.	Value per ton.		
Dry solid matter of	lbs.	lbs.	lbs.	£	s.	d.
Recent fæces . .	124·98	113·67	40·40	5	17	7
Do. artificially dried . . .	112·63	121·08	38·17	5	9	6
Fresh sewage . .	147·67	32·08	48·20	6	3	2
Do. artificially dried . . .	40·10	24·42	68·32	2	9	7
Do. do. do.	28·67	35·16	60·88	2	1	5

The plain inference from this is that the agricultural value of these materials is greater when they are in a recent or fresh state than when they are consolidated by any process of drying, and that if sewage is to be profitably utilised it must be employed in a liquid form. The great difficulty, however, is the utilisation of it at all times, in all seasons, and with every description of soil. Water alone, under some circumstances, as in the dry warm climates of Egypt, China, Persia, Piedmont, Lombardy, and elsewhere, has been successfully used for irrigation purposes for ages, and has given fertility to districts that would otherwise have been barren. Even in this climate the judicious use of water at the right time has been found profitable ; for, as Bacon says, "it maketh an ex-

cellent improvement for both corn and grass, profiting them much ;" but it must be used in proper times and with proper soils. The same is the case with sewage, which undoubtedly has a somewhat higher manurial value than water. "I would give," says Mr. Lawes, "2d. a ton for the sewage of London delivered in such quantities and at such times as I required it, but I would not give a half-penny a ton for it if I were obliged to take it all the year round, and have to pay the expense of sub-piping and carriage through the farm ;" and we doubt if we would take it at any price if we were bound to use it, and deliver the water from it in such a condition as to be admissible, without offence, into the neighbouring streams. These, in fact, are the great difficulties of the question ; for there is no description of soil, and no variety of crops that will receive sewage profitably at all times. In the frost of winter, and during the heavy rains of spring and autumn, the land is impenetrable to sewage, and it flows away unchanged to the nearest water courses. During the maturity and ripening of crop also the use of sewage is always inadmissible. According to Mr. Lawes, the application of sewage, all the year round, as it should be applied to meet the sanitary demands of the case, is wholly unsuited for arable land ; but if a person can apply it to-day and not to-morrow, just as he pleases, he may use it for all crops. Professor Way holds to the same opinion ; for he says, "if the farmer is bound to take large quantities of sewage at all times, he would soon decline to take it at all. He could not do it in times of rain like June, July, or October (1862)." Evidence to the like effect has been given by Mr. Congreve, who managed one of the sewage farms at Rugby, and who found, after eleven years' experience, that the thing was often unmanageable. "If I had a farm," he says, "in the neighbourhood of London, I would take sewage if I were at liberty to have it when it suited my purpose, and I would apply it over a very limited area at a certain time of the year ; but if I were compelled to

take it at all times I should refuse it altogether." Mr. Mechi, the champion of sewage irrigation, is evidently of the same opinion ; for he says he would rather not be regulated as to the time of applying it, but would use it when he wanted it. This is the way in which it is dealt with at Worthing, at Birmingham, at Edinburgh, at Carlisle, and some other places where the parties know what they are about ; and this was so strongly impressed on the parliamentary committee of 1862, that they say in their report on the subject, "that it is desirable that those using sewage should have a full control over it, so that they may apply it when and in what quantities they may require ;" and they quote the evidence of Mr. Lawes, Mr. Way, Mr. Tregelles, Mr. Samuel Christy Miller, Mr. McCann, and Mr. Miles in proof of it. In point of fact, almost every witness who appeared before the two committees spoke of the great difficulty of managing a sewage farm so as to get rid of the sewage at all times.

A good deal of difference of opinion exists as to the proper time for using sewage. Mr. Mechi applies it to pasture land from the 1st of May to the 20th of June ; and when cattle are feeding on the land he uses it at all times during active vegetation. The Earl of Essex puts it upon meadow land for hay from October to January or longer, and in summer time he uses it after each crop of Italian rye grass. At the Craigentinny meadows the land is drenched with sewage directly after each cutting. Mr. Treggelles uses it for pasture land in winter, and for root crops in summer—turning it upon swedes when they are as big as marbles, and upon mangolds while they are growing. There is, however, no fixed rule in the matter—the farmer being guided by the season, and the actual wants of the crop as regards drought, &c , the returns being always most profitable in dry weather.

There is the same difference of opinion respecting the mode of applying the sewage. Mr. Smith, of Deanston, Mr. Edwin Chadwick, Mr. Mechi, Mr. Telfer, and Mr. K nnedy were for irrigation by means of the hose and jet ;

and this is still recommended by many persons. It was the plan which the Select Committee of the House of Commons on the Sewage of Towns thought most advantageous; for in their final report and analysis of evidence (1862), they say that the evidence proves "that by the hose and jet, sewage may be much more economically applied than by open carriers." This no doubt is the best way to effect the purification of sewage and the utilisation of all its manure constituents, but the plan has never been commercially successful. "If," says Professor Way, "you ask me how I am to make, regardless of cost, the manurial ingredients of the sewage into the greatest amount of produce of any kind, then I would put it on with pipes and hose in small quantities, almost as I would in garden cultivation—as if I were watering it with watering-pots, but it would never pay to do it. With hose and jet you would never get the quantities on that it would pay you to put it on. This is abundantly proved by practice, for no where, except for fancy use, is the hose and jet system employed. It was tried at Rugby by Mr. Walker, Mr. Congreve, and Mr. Campbell, and was at last abandoned; and the same was the case at the farms of Mr. Telfer and Mr. Kennedy. It has come, therefore, to this, that sewage, when it is used at all, is distributed upon the land by open carriers, and made to flow in large volumes upon the surface of the ground. At Mr. Hope's farm at Romford, where the sewage is most judiciously treated, it is first pumped to the top of the farm by an engine, and then conveyed by sheet iron troughs to about the centre of the farm, where the conduits branch off in all directions—there being out-lets at short intervals, which can be opened by a plug so as to let out the sewage upon the land. At Carlisle the sewage is distributed upon pasture land by means of moveable troughs; but generally it is run through open gutters or carriers, which are dammed up at certain points so as to make the sewage overflow and flood the land.

But, however the process is conducted, it requires a thorough change in the whole system of farming, and must

revolutionize the common mode of working; and the land must be specially prepared to receive it. It must be levelled, and drained, and put in order, so that the sewage shall flow successively over different portions of ground, and shall not pass away without undergoing the needful purification. And all this, as Mr. Lawes observes, is quite a special mode of farming, being totally different from the ordinary farming operations of the country. It might be said, indeed, that it is retrograding to the old times when the farmer put the weakest sort of compost upon his land, using only the dung of his working animals, and the refuse of his fields for manure; but the experience of the last thirty years has shown him that all this was wrong, and that to keep pace with the competitive progress of free trade, he must fertilise his land with the richest manures. Guano was imported in 1835, and superphosphate, at the suggestion of Liebig, was manufactured in 1841. These, with other forms of rich portable manures, have for twenty years been growing more and more into favour on account of their profitable results; and now, instead of using the old fashioned stable dung of his working animals, he manufactures manures of the richest quality by feeding stock under cover on cake, pulse, and cereals—showing that there is direct relation between the food of the cattle and their ordure. Here is a Table constructed by Mr. Lawes, of Rothhampstead, which shows the estimated value of the manure from a ton of different kinds of fodder.

Value of the Manure from a Ton of the Food.

Description of Food.	£	s.	d.	Description of Food.	£	s.	d.
Decorticated cotton seed-cake . .	6	10	0	Indian corn . .	1	11	6
Rape cake . .	4	18	0	Malt	1	11	6
Linseed cake . .	4	12	0	Barley	1	9	6
Malt dust . . .	4	5	0	Clover hay . .	2	5	0
Lentils	3	17	0	Meadow hay . .	1	10	0
Linseed	3	13	0	Oat straw . . .	0	13	6
Tares	3	13	6	Barley straw . .	0	12	6
Beans	3	13	6	Wheat straw . .	0	10	6
Peas	3	2	6	Potatoes . . .	0	7	0
Locust beans . .	1	2	6	Mangolds . . .	0	5	0
Oats	1	14	6	Swedish turnips .	0	4	3
Wheat	1	13	0	Common do. .	0	4	0
				Carrots	0	4	0

The richer descriptions of farm-yard manure obtained by feeding horned stock under cover on chaff, roots, corn, oil-cake, pulse, &c., mixed with the manure of the corn and bean-fed horses and well-fatted pigs, constitute, with such portable manures as guano, superphosphate, and the salts of ammonia and potash, the fertilising agents which have revolutionized the practice of British farmers; and it is hardly likely that, with such experience of the value of rich composts they will adopt the suggestion of flooding their lands with the miserably weak sewage of towns.

As to the quality of soil which is best suited for sewage irrigation there is likewise much difference of opinion. Most agricultural chemists of large practical experience advocate the use of a porous sandy soil. Dr. Voelcker, for example, says that all liquid manures produce the most beneficial and striking effects when they are applied to light, deep, and sandy soils, resting upon a porous subsoil —soils containing from ninety to ninety-six per cent. of sand and but little alumina, so that the sewage may go through it and not over it. Professor Way also states that

he would select a pure sandy soil in preference to anything approaching clay, because sand will become richer in clay every year that sewage is applied to it—apart from the fact that clay can always be added to sand if necessary, whereas no clay soil can be made open enough to receive sewage—in fact, "a dry absolute clay is," he says, "the last soil I should wish to use sewage upon, because although it has the power of extracting manurial qualities of sewage, the sewage cannot get into it. Even if the clay were ever so well-drained, the liquid would run over it." According to Mr. Lawes it is best applied to the most porous, sandy, and sterile soils, like that of Bagshot Heath, and the same opinion was entertained by the late Sir Joseph Paxton.

On the other hand, some chemists are of opinion that the soil should contain a notable proportion of clay, because clay has the largest power of absorbing ammonia, phosphoric acid, and potash—the most important constituents of sewage. Baron Liebig opposed the scheme for distributing the sewage of London upon the Maplin sands, because they do not contain sufficient clay, and he attributed the success of the Craigintinny meadows at Edinburgh, to the circumstance of their containing much alumina. He thought, indeed, that the Maplin sands would require at least two million tons of clay to give them fertility to the depth of an inch.

Mr. Bailey Denton, who has recently acquired popularity in connection with this subject, is of the same opinion, and argues that a soil with a considerable portion of clay is better than a very porous soil, because it delays the percolation of sewage, and retains the manurial elements. But then the land must be thoroughly drained, for that is Mr. Bailey Denton's speciality, and he blames the Rivers Pollution Commissioners for not making it a *sine quâ non* that no irrigation should be practised without deep subsoil drainage.

The value of clay as a constituent of ordinary soil is admitted on all hands, for it not only absorbs and

fixes the chief elements of manure, but it also elaborates them, and fits them for the use of the growing plant. This power was first investigated by Brouner in 1836, and afterwards, in 1845, by Huxtable and H. S. Thompson. Later still, in 1850, 1852, and 1855, it was still further examined by Way, who thought that the absorbent power of a soil was dependent on the chemical action of certain silicates of lime and alumina, which fixed the alkaline bases, and allowed the acid constituents (phosphoric acid excepted) to pass in combination with lime. Liebig's views at first were entirely opposed to these opinions respecting the absorptive power of soils ; but, in 1858, he ascertained from experiment that every plant-bearing soil absorbs the fertilising elements of manure—clay doing it best, and pure sand worst—whilst turf and peaty matters had an intermediate action. He found that a common clay soil in the neighbourhood of Munich would absorb (per acre, four inches deep) 2,076 lbs. of ammonia, 1,910 lbs. of potash, and 888 lbs. of phosphoric acid ; and that the action was not merely of a physical nature, for it seemed to prepare and elaborate the materials for the use of the plant—acting, in this respect, like the stomach of an animal. Voelcker also found in his experiments that all soils absorb ammonia from its solutions, clay doing it best, and organic matter worst, the difference in other soils being but slight. He ascertained, however, that the whole of the ammonia was never, in any case, entirely removed, however strong or weak the solution of it was, and that water would subsequently wash it out again, to some extent, though not completely. Potash salts were most freely absorbed by clay, and hardly at all by sand ; and with respect to the phosphoric acid of soluble superphosphate, it is absorbed and rendered insoluble by all arable soils—chalky and marly soils acting more powerfully than clay or sand—the change being not immediate, but the work of time, and requiring a large proportion of soil.

The agents which are chiefly concerned in these remark-

able effects are alumina and hydrated oxide of iron, with lime and other bases. Warrington, indeed, has proved that, although all the constituents of a soil, except quartz, have the power of absorbing manurial elements, yet alumina and hydrated oxide of iron possess it to the largest extent, the order of absorption being as follows :—for acids, phosphoric, carbonic, sulphuric, muriatic, and nitric ; and for bases—ammonia, potash, magnesia, lime, and soda—the form in which the base is best appropriated being the hydrate, phosphate, or carbonate ; the sulphate, nitrate, and chloride being but slightly absorbed. The extent to which the solution is diluted is also a matter of considerable importance ; for, although Liebig and some others are of opinion that the soil will appropriate the manurial elements of a solution, no matter how dilute it is, yet Voelcker has proved beyond all question that weak solutions, like sewage, will actually remove those elements from a soil, and that unless a plant is growing, and is therefore able to appropriate the elements of sewage at the time it is applied, there is no power in the soil to arrest the elements, and to store them up for future use, when they are continuously applied in such a weak form. The action of the soil, therefore, under such circumstances, is merely to strain the liquid, and to effect the oxydation of its nitrogenous compounds, which pass away as nitrates and are entirely lost. This is easily proved by an analysis of effluent sewage water when vegetation is inactive, and the plant is unable to appropriate nitrogenous matters ; for at such times, the sum total of all the soluble nitrogen in the sewage is found in the effluent water in the form of useless nitrates. It is very doubtful, indeed, whether at any time the nitrogenous matters of sewage are entirely utilised by the plant, even in its most vigorous state of growth, and whether the plausible theories which are so rife concerning the value of ammonia, &c., in sewage, are not altogether erroneous. A glance at the table which is given at page 46 of the Third Report of the Commissioners appointed to inquire into the best mode of distributing

the sewage of towns (1865), will show that the amount of soluble organic matters of sewage, as estimated by the process of incineration which was then in use, is not very different from that in the effluent water.

"AVERAGE COMPOSITION OF THE SEWAGE AND DRAINAGE WATER COLLECTED AT RUGBY IN THE SEASONS OF 1862 AND 1863.

GRAINS PER GALLON.

Season 1862—*May to October, both inclusive.*	Soluble Organic Matter.	*Season* 1863—*Nov.*, 1862, *to October*, 1863, *both inclusive.*	Soluble Organic Matter.
Five acre field—		*Five acre field*—	
Raw sewage . .	7·83	Raw sewage . .	8·35
Effluent water .	7·18	Effluent water .	7·46
Ten acre field—		*Ten acre field*—	
Raw sewage . .	7·60	Raw sewage . .	8·30
Effluent water .	7·83	Effluent water .	7·98
The two fields—		*The two fields*—	
Raw sewage . .	7·71	Raw sewage . .	8·32
Effluent water .	7·56	Effluent water .	7·73

These were the results of sixty-two analyses; and in commenting on them the Commissioners say that, "of the matter in solution, a gallon of drainage water contained sometimes more and sometimes less, but on the average much about the same amount, both of organic and inorganic as a gallon of the sewage." In criticising this remark, the Commissioners appointed in 1868 to inquire into the best means of preventing the pollution of rivers (First Report, 1870, p. 71) say,—"There can be no doubt that these results, and the statement founded upon them, so far as it relates to organic matter, are erroneous, and that the cause of the fallacy lay chiefly *in the absence of nitrates in the raw sewage, and their presence in large quantities in the effluent water.*" But in many cases, the oxydation is far from being complete, especially when the land is overtaxed. Professor Way says that if sewage be

put upon a soil in larger volume than about 1,500 tons per acre per annum, even with rich growing Italian rye-grass, the sub-soil water is foul. The same fact was observed by Mr. Westwood, of the Annerley School Farm, who found no difference in the results, as regards the crops of rye grass, whether he used 1,500 tons per acre by hose and jet, or from 8,000 to 9,000 tons per acre by open carriers ; but in the latter case the effluent water was almost as foul and as high coloured as the original sewage. In the experiments at Rugby, Mr. Lawes noticed that, although there was an additional crop of grass with an increased flow of sewage, yet it was by no means in proportion to the quantity used ; for, while with 3,000 tons of sewage an acre he got 22 tons of grass, yet with 6,000 tons an acre he got no more than about 28 tons of grass, and with 9,000 tons an acre only 32 tons of grass. It is evident, therefore, that neither the plant nor the soil is capable of appropriating all the manurial elements of sewage, and that, therefore, they must pass away in a more or less oxydised and useless form.

This brings us to a question of great practical importance, namely, how much sewage can be profitably and safely applied to a given area of land. On this head, as on every other, there is the greatest difference of opinion, although it results generally in the fact that the sanitary and commercial aspects of the question are widely opposed, it being impossible to realise agricultural success, with a perfect deodorisation of sewage ; for, in one case a large proportion of sewage is required, and in the other a small.

In illustration of the great difference of opinion among theoretical and practical men, as to the quantity of sewage that ought to be applied to a given area of land, we may quote the remarks of Mr. Lawes, on the evidence given before the Select Committee of the House of Commons, "On Sewage of Town." "One witness who had been engaged for years in the application of sewage, and whose evidence is said in the 'Analysis of Evidence,' to be

'entitled to great weight,' gave it as his opinion that, 300 tons of sewage per acre would accomplish the same results as the 10,000 tons which he had, in point of fact, applied. Another witness, just returned from a visit of inspection of the sewage meadows at Edinburgh and Rugby, considered the inferiority of the produce at Rugby, to be due to the much smaller quantity of sewage there applied, the amount ranging from 3,000 to 9,000 tons per acre; whilst, in the case of the Edinburgh meadows to which he referred, it was estimated by the same witness at 10,000 to 12,000 tons per acre, and to be as high as 30,000 to 40,000 tons on some of the meadows in that locality." There are authorities in fact who declare that as little as 100 tons of sewage per acre per annum is sufficient for agricultural purpose. Mr. George Shepperd, a sewage engineer of some notoriety has expressed this opinion, and so also has Mr. Mechi, the champion of sewage farming, whose mode of reasoning is somewhat as follows:—A human being is equal to a sheep in manurial value. Now in England, according to statistics, the land only receives the manurial results of two sheep per acre per annum from all the farm animals in the country, reckoning bullocks, horses, pigs, &c., in their proper equivalent proportions as sheep. Therefore, says Mr. Mechi, the manure of two persons is enough, as a normal dressing, for ever acre of land; and this is just 100 tons of ordinary sewage, when the water supply or degree of dilution is at the rate of thirty gallons per head daily. But experience has shown even under Mr. Mechi's supervision, that twice this amount is insufficient. The experiments to which we allude were made at Rugby some years ago by Mr. James Archibald Campbell, who brought with him from Edinburgh, as we have before said, the largest notions of the agricultural value of sewage, and being desirous of realising at Rugby the sewage wonders of Edinburgh, he became an enthusiastic sewage farmer, taking about 190 acres of land from Mr. Walker, and agreeing to pay him a guinea an acre for five dressings of sewage applied to the

land between the months of March and October. At the onset, says Mr. Campbell, a question arose as to what constituted a dressing, and it was left to Mr. Alderman Mechi to say how much it should be. That gentleman, after grave deliberation, decided that the quantity was to be 9,000 gallons, or 45,000 gallons per acre for the five dressings. This is almost exactly 200 tons an acre ; but it was soon found to be insufficient ; and year by year he went on reducing the area of land until he put the whole of the sewage, for which he paid £150 a year, on about twelve acres of land. In a pamphlet published by Mr. Campbell, in which he gives the results of his experience for eight years as a sewage farmer, he states "that he should expect a better paying return from fifty acres with 4,500 tons per acre per annum, than from 100 acres with 2,250 tons an acre." Mr. Mechi could hardly fail to profit by these results, and so he has since recommended that from 500 to 600 tons of sewage per acre should be applied to the land. He has even said that for green crops 1,000 tons might be used, and perhaps, in the case of London sewage as much as 2,000 tons an acre ; although he cannot forget that his friend, Mr. Miles, of Bristol, produces excellent results with the sewage of thirty persons upon fourteen acres of land. Mr. Thomas Ellis, who was a candidate for the sewage of London, proposed that it should be distributed at the rate of 500 tons an acre per annum, and his views were strongly advocated by Mr. Brady, the chairman of the Select Committee on Sewage. Reasoning in much the same way as Mr. Mechi, he said that "as good results were obtained from twenty tons of farm yard manure upon an acre of land, and as thirty tons of sewage were equal to at least one ton of rich manure, it was evident that 600 tons of sewage per acre were enough for all practical purposes." This is the produce of a dozen people, and is therefore an extravagant allowance when compared with the fancy farming of Mr. P. S. Miles, of Bristol.

Messrs. Hope and Napier, whose scheme for the utilisation of the northern sewage of London upon the Maplin

Sands, and Dengie Flats, was accepted, with some modifications by the Metropolitan Board of Works, were of an opinion that 1,750 tons an acre are sufficieut for profitable results ; and very recently at the meeting of the British Medical Associatiou at Plymouth, Mr. W. Hope read a paper "On Sewage Irrigation iu connection with Public Health," wherein hc stated that in most cases the sewage farms of this country were, as Dr. Letheby and Mr. Hawksley had described them, pestilential swamps ; and this he attributed to the application of sewage in too large quantity, especially during the night when plants could not utilise it. He therefore recommended that sewage should be sparingly used—an acre of land being allotted to every twenty or thirty persons, as "it seemed exceedingly doubtful whether, having regard to the commercial side of the question, it would be practicable to utilise the sewage of more than twenty or thirty persons per acre over a term of years." This is at the rate of from 1,000 to 1,500 tons of sewage an acre per annum; and it is we believe the quantity used by Mr. Hope, upon the 121 acres of Breton's farm, near Romford, of which he is thc lessee. A like opinion was entertained by Mr. Westwood, the farm Bailiff of the School farm at Annerley ; for he said in his evidence before the Parliamentary Committee, that when morc than 1,500 tons an acrc was applied to the land (clay) it ran away into the drains, and fouled the stream. He found this to be the case with ground receiving from 8,000 to 9,000 tons an acre, even when it was cultivated with rye-grass. Baron Liebig also is of opinion that small dressings are more advantageous thau large, because sewage ought not to sink deep and be lost. A soil, in fact, saturated with manure not only fails to increase the crop, but becomes, except in the case of roots, positively hurtful. Meadow land, he says, to yield four tons of hay per acre, or twelve tons of grass, would rcquire 2,430 tons of sewage ; and even then about two-thirds of the ammonia and one-third of the phosphoric acid arc lcft unutilised—the potash only of the sewage being appropriated. On the other hand th

Earl of Essex, who was the chairman of the commission appointed to inquire into the best mode of utilising the sewage of towns, and who rents the sewage of Watford, began by distributing 60,000 tons of sewage annually upon 210 acres of mixed arable and grass land which he had under-piped, but he found it was necessary to limit its application to a much smaller area, and almost exclusively to either permanent meadow or Italian rye-grass. He stated in fact in his evidence before the Committee of the House of Commons, that practically he had limited it to about ten acres of rye-grass, and thirty-five acres of meadow land—"I put," he said, "about 5,000 or 6,000 tons a year to each acre of Italian rye-grass, and 600 tons on each acre of meadow land—making between 60,000 and 70,000 tons which I calculated I got from the 4,000 inhabitants of Watford." This is the quantity which is used at Croydon, Banbury and Warwick. Dr. Voelcker is of opinion that from 2,000 to 4,000 tons an acre may be put upon better kinds of land, but that porous soils of a sandy nature will take from 8,000 to 10,000 tons per acre. "When," he says, "we apply a large mass, say 7,000 to 8,000 tons to a soil which is naturally porous and deep we incorporate with a large body of soil a considerable quantity of solid, real fertilising matter. By using such large doses upon grass crops grown upon a poor soil, these solid manuring matters which are disseminated through a large body of soil by capillary attraction, are brought within reach of the roots of the plant. The evaporation which takes place from the leaves of grass crops is very considerable; the moisture from a considerable depth is drawn up, and with it all the solid matters dissolved in it. Then we see a marked effect upon vegetation, which will explain in practical experience, why quantities of 300 to 400 tons an acre, even applied to grass lead to no practical result, whilst large quantities applied to the extent of 8,000 or 9,000 tons (and I am not sure that even larger quantities may not be used with advantage) produce a good result. That is a matter which is clearly determined by

experiment; for I have nowhere seen such small quantities as 300 or 400 tons an acre produce any decided beneficial and remunerative effect." Professor Way has arrived at the same conclusion, for in speaking of the sewage of London, he said that "you could advantageously use the sewage of 3,000,000 people upon 30,000 acres of land, which would be the excreta of 100 people per acre, provided it was all grass land; but it would be advantageous to take a larger area, because the only way in which you can deal with it is by feeding it into milk, or into flesh, and you would have a very large quantity of manure produced by the cattle in addition to the sewage; consequently, you will have the means of returning an increased quantity of manure to the land." Mr. Lawes, after a careful consideration of the subject, decided to apply it experimentally at the rate of from 3,000 to 9,000 tons an acre upon the land at Rugby, and the results of his experiments were that less than 5,000 tons an acre were not sufficient for profitable returns. Mr. Robert Rawlinson, who once had the most extravagant notions of the value of sewage, has since learnt, and candidly admitted, that an acre of land is required for every 100 persons, which is at the rate of 5,000 tons of sewage per annum; and Mr. Bailey Denton, whose views of this subject are rather peculiar, is nevertheless of opinion that for actual working an acre is required for every 100 or 150 persons, according to the porosity of the soil—lighter soil taking the sewage more freely than heavy; but still he thinks that extra land is necessary on various reasons, and especially for alternate cropping, and for occasional rest of the land. He says, indeed, "that the excrement of five persons, worth thirty shillings per annum, is equal to as many loads of farm-yard manure, and will do for a rood of ground, worked with reference to cropping, and applied to half the land each year." This is at the rate of only twenty persons to an acre, or forty for the land actually in work. Even supposing that the excreta are applied in a concentrated form, Mr. Bailey Denton's views are very different from those of the late Sir Joseph Paxton, who said in his

evidence before the Parliamentary Committee that he could put the sewage of 250 persons upon an acre, when it was not diluted with more than a tenth part of the water in London sewage—whereas in the latter case it would require 30,000 acres for its appropriation. At Edinburgh, however, the sewage of about 80,000 persons is put upon 250 acres of sandy soil; and this is at the average rate of 16,000 tons an acre; although in practice it ranges from 10,000 to 40,000 tons an acre according to the requirements of the crop.

It comes, therefore, to this, that after an experience of nearly twenty years, in every variety of situation, season, and soil, with all the enthusiasm and diligence necessary for success, the so-called practical men are unable to declare definitively what quantity of sewage can be safely and profitably applied to a given area of land; for in active practice it ranges as we have seen from 100 tons an acre per annum to 40,000 tons; or, to put it in the form of acreage to the population, it ranges from two persons per acre to 800 persons. What further proof is necessary of the difficulties of the whole question, and of the uncertainty of the conditions upon which even a partial success is dependent? One thing, however, is conclusive, and that is the diametrically opposite conditions of sanitary and agricultural success, for while in the one case, a limited supply of sewage to the land is necessary, the other it must, at certain times, be almost unlimited. To be safe in fact, as regards freedom from nuisance, the land must never receive more than from 1,000 to 1,500 tons of sewage per acre per annum; whereas for commercial profit it must never have less than 5,000 tons an acre; in the former case it represents a maximum of thirty persons to an acre, and in the latter a minimum of 100 persons.

Next, as regards the crop to which sewage irrigation is most suitable. Some are of opinion that it is applicable to every description of produce provided it is used at a proper time and in proper quantity, though others assert

that it is only fit for grass crops and succulent roots ; all however are agreed that it is most profitably applied to Italian rye-grass and to pasture land ; and that it will in dry seasons augment the yield of hay if it be used at a proper time. The Earl of Essex began by distributing it over arable as well as grass land, but he ended by limiting it almost entirely to permanent meadow land and Italian rye-grass. The same was the case with Mr. Campbell at Rugby, although both of them think that sewage is good for roots in dry weather, and even for wheat at a proper time. Mr. Mechi says it is best not to apply it to the land immediately for wheat, but to a preceding root, grass, or clover crop, because if it is applied to wheat it causes it to be too luxuriant, and to full early. Mr. Congreve, of Rugby, is evidently of the same opinion, for he says it will increase the quantity of straw but not of corn ; and he adds that although it will greatly promote the growth of grass, both natural and artificial upon poor land, it cannot be applied with good effect to roots, because it contains so much water that your land is in a state of sea if any quantity is upon it. Mr. Miller, of Edinburgh, has arrived at the like conclusion, for he found it made furrows and channels in arable land, and washed the roots of plants bare. It was in fact positively hurtful to wheat and he doubted if its immediate application was of any benefit to turnips. Dr. Voelcker, Professor Way, and Mr. Lawes have expressed themselves to the same effect, and have condemned the use of sewage for arable land. "It may," says Dr. Voelcker, "be fit for pasture land and for raising coarse green crops, but it is quite unfit for cereals after the grassy state, because of its forming straw instead of grain, and checking the ripening process." It is even unsuited, in his opinion, for market produce, as it clogs the soil and kills the plant. Mr. Way also advocates the use of sewage upon grass land, because it is the only way in which you can deal with it, by feeding it into milk or flesh, and so getting a more manageable manure. While Mr. Lawes, in his article on the "Utilisation of Town Sewage," says that "it seemed impossible to account for

the abandonment, at Watford and at Rugby, of the use of sewage to crops generally, and in comparatively small amounts per acre, after so large an outlay had been incurred entirely with a view to its application in these very ways, excepting on the supposition that the practice was not found to be profitable ;" and in the combined report of these gentlemen on "The Sewage of Towns," they say, in general conclusion, that "where the most extensive trials of the application of sewage to corn crops have been made with a view to profit, namely, at Watford, Rugby, and Alnwick the practice has been abandoned, whilst neither at Edinburgh nor Croydon, where the best results have been obtained with grass, does the application to corn and other rotation crops constitute a part of the general system adopted. Judging both from the results of the experiments, and from the experience of common practice, it is considered that the most profitable utilisation of town sewage will in most cases be obtained by the application of about 5,000 tons per acre to meadow or Italian rye-grass,"—both of which are most profitably used for feeding stock or for dairy purposes. This however is not the opinion of Mr. Bailey Denton, who thinks that Italian rye-grass is a mistake, and that stock-feeding and dairy-farming are a delusion. In his lecture last year to the Maidstone Farmers' Club on "Sewage Irrigation as a means of disposal of Town Sewage," and in considering by what description of crops the sewage farmer would most profit, he stated "that Italian rye-grass had hitherto held a permanent place ; but with this he did not agree," and he gave statistics to prove that generally speaking the cultivation of grass on sewage farms was unprofitable. "Mangolds, beet, turnips, carrots and parsnips, potatoes and cabbages—the latter especially—he recommended as good crops for the sewage farmer ;" and he quoted Mr. Petre, of Lodge farm, and Mr. Hope, at Breton's farm, in proof of it. He even advocated "the production of straw upon a sewage farm as a matter of great moment ;" for although the quantity of grain was small, the bulk of straw was large, and this was advantageous in feeding stock. "In

the main however," said Mr. Bailey Denton, "the less the sewage farmer dealt with stock, and those other branches of farming which were not essential to a sewage farm the better, for he would require all his attention to be devoted to the essential duties of the farm, and the marketing of its regular produce."

Baron Liebig, also, is of opinion that sewage is less adapted for grass crops than for any other, because of its containing more ammonia and phosphoric acid, in comparison with potash, than the plant can utilise, and that its full value can only be realised on pasture land. "Suppose," says Liebig, "that we wished to produce yearly 12 tons of grass per acre, or 4 tons of hay—What quantity of sewage would be required to furnish the material? A ton of good, but not super-excellent hay, contains 36 lbs. of nitrogen—equal to 43 lbs. of ammonia, 18 lbs. of phosphoric acid, and 31 lbs. of potash; 4 tons of hay, therefore, will abstract from each acre of land 172 lbs. of ammonia, 72 lbs. of phosphoric acid, and 124 lbs. of potash. Now, as it is a law of husbandry that the effect of all the constituents of a manure is but the effect of that one of them, which, in comparison with the wants of the plant, is present in the smallest quantity, it follows that, to obtain the 124 lbs of potash, which is the smallest proportional constituent of sewage, we must use about 2,400 tons of sewage; and this contains 547·73 lbs. of ammonia and 109·6 of phosphoric acid. There is, therefore, an excess of 375·73 lbs. of ammonia and 37·6 lbs of ammonia, which are left unutilised in the soil. The effect of this, according to Liebig, is not merely wasteful, but is actually injurious, for it clogs the soil, and at last kills the plant. It is manifest, therefore, that if potash and phosphoric acid were added to sewage, so as to bring their proportions up to the requirements of the crop, less sewage would be necessary, and greater fertility secured; and with the view of ascertaining how this may be accomplished, he gives on the one hand the percentage composition of the mineral constituents of plants, from which we can learn their mineral require-

ments, and, on the other, the proportions of the chief elements of ordinary manures—and thus see the means of supply :—

PERCENTAGE COMPOSITION OF THE ASH OF PLANTS.

	Potash.	Phos. Acid.	Limes, &c.	Potash to Phosphoric Acid.
Wheat	30	45	25	10 to 15·0
Pulse	40	36	24	,, ,, 8 5
Potatoes... ...	54	18	28	,, ,, 3·3
Cabbages ...	42	20	38	,, ,, 4·8
Hay	18	11	71	,, ,, 6·1

A similar table, but more comprehensive, is given by Messrs. Lawes and Way in their Third Report on "The Sewage of Towns" (1865, p. 35).

PROPORTION OF PHOSPHORIC ACID AND POTASH TO ONE OF NITROGEN IN VARIOUS PLANTS.

	Phosphoric Acid.			Potash.		
	In Corn, Roots, &c.	In Straw, Leaves, &c.	In Total Produce.	In Corn, Roots, &c.	In Straw, Leaves, &c.	In Total Produce,
Wheat ...	0·48	0·42	0·46	0·28	1·08	0·57
Barley ...	0·40	0·34	0·38	0·34	1·26	0·60
Oats ...	0·28	0·37	0·30	0·25	1·55	0·65
Meadow hay	—	—	0·27	—	—	1·00
Clover hay ...	—	—	0·23	—	—	0·52
Beans ...	0·25	0·46	0·30	0·32	1·23	0·50
Mangolds ...	0·17	—	—	1·00	—	—
Swedes ...	0·27	0·16	0·21	0·82	0·44	0·63
Com. turnip	0·28	0·18	0·26	1·60	0·71	1·17
Potatoes ...	0·42	—	—	1.23	—	—

And with respect to the proportions of ammonia, potash, and phosphoric acid in sewage and other manures, they are as follows :—

PROPORTIONS OF PHOSPHORIC ACID AND AMMONIA TO 10 POTASH IN SEWAGE, GUANO, AND ROTTEN FARMYARD DUNG.

	Potash lbs.	Phos. Acid lbs.	Ammonia lbs.
193 tons of sewage yield ...	10	8·8	44.1
2,023 lbs. of farmyard dung	10	9·0	14·9
1,672 lbs. of Peruvian guano	10	200·5	142·3

So that if 20 tons of rotten farmyard manure be put upon an acre of land (and this is considered a good average dressing) they will yield 330 lbs. of ammonia, 200 lbs of phosphoric acid, and 220 lbs. of potash ; but the quantity of sewage (1,446 tons) required to yield the same amount of ammonia would contain only 75 lbs. of potash, and but 66 lbs. of phosphoric acid ; and the equivalent of guano (3,877 lbs), according to Liebig's analysis, would contain 465 lbs of phosphoric acid, and only 23 lbs of potash. While, therefore, guano is rich in phosphates and ammonia, and poor in potash, and farmyard manure is the reverse of this, sewage occupies, according to Liebig, an intermediate portion, and represents a mixture of the two—especially if a little phosphoric acid is added to it in the form of soluble superphosphate. This he illustrates in the following manner :

	Ammonia. Tons.	Phos. Acid. Tons.	Potash. Tons.
728,767 tons of sewage contains ...	75	15	17
275 tons of superphospate	—	75	—
Total ...	75	90	17
2,650 tons of farmyard manure	19·5	11·8	13·1
652 tons of Peruvian guano	55·5	78·2	3·9
Total ...	75·0	90.0	17·0

These are in the proportion of 845¼ lbs. of superphosphate to every 1,000 tons of sewage. The chief value of sewage, therefore, according to Liebig, is that by its use, the effects of phosphates, of guano, and of stable dung are made sure and lasting, and the produce of the land raised to a maximum. On this account it should never, in his opinion, be used alone, but in conjunction with richer manures. Other agricultural chemists are not exactly of this opinion, for, according to Dr. Voelcker, when the soil itself contains the elements of fertility, sewage has no more value than so much water, and will not remunerate the farmer for the expense of its application. In the case of soils naturally poor and barren, the conditions, he says, are altogether different, for then a copious application of town sewage will produce abundant crops of grass, when nothing else will grow of any agricultural value. In commenting on these remarks of Dr. Voelcker, the editor of the *Agricultural Gazette* (Mr. Morton, who is now one of the Rivers' Pollution Commissioners), said "that the lecture of Dr. Voelcker, reported in the *Gazette* for May 31, has probably done more than anything hitherto made public to determine the vexed question of the true value of town sewage, and to dissipate many of the flattering illusions entertained upon the subject; for he appears clearly to show that town sewage is of little value as an application to arable land or for horticultural purposes." Other observers have arrived at the same conclusion, and have reported that its effects were no better than those produced by water, except that when too copiously applied it always killed the tender herbage, and produced a rank description of grass.

As might be expected, the nutritive value of a crop which has been raised upon land flooded with sewage is not remarkably high, and this is especially so with root crops and succulent vegetables; for, although the bulk and aggregate weight of the crop are often considerable, yet, the relative proportion of solid nutriment in it is al-

ways small ; besides, which, the produce is difficult to dry, and from its succulent and immature quality, it is very prone to putrefactive decomposition. It can rarely, in fact, be stored or otherwise treated like the produce of unsewaged land, and must, therefore, be consumed in its fresh or green condition. In commenting on the fact that irrigated meadow land did not yield so nutritious a product as natural pastures, Dr. Voelcker states that this is generally the case with all kinds of produce ; for just in whatever degree an abundance of manure was applied, and larger crops were obtained, in that degree would the quality of the crop be inferior. The rule, he says, holds good for wheat and barley, and even turnips. If you want something good you must be content with a small quantity, but if you want much you must take it in a cruder condition. "In fact," to use his words, "the more rapidly produce is grown the less mature it is, and the more likely to produce disorders in the animal economy ; whilst bulk for bulk, the poorer the meadow the more scanty the herbage, and the more slowly it grows the better and more nutritious it is."

In the years 1861, 1862, and 1863, experiments were made at Rugby by Mr. Lawes, on the part of the Royal Sewage Commission, of which he was a member, for the purpose of ascertaining the value of sewage grown grass as a means of fattening cattle and producing milk. Two plots of meadow land of different qualities were selected at a distance of a mile from each other,—one called the Five Acre Field, and the other the Ten Acre Field ; and each of them was divided into four plots—one plot being left in its natural state without sewage, and the other plots were respectively irrigated with sewage at the rate of 3,000 tons, 6,000 tons, and 9,000 tons per annum. During the first year, the sewage was applied for eight months only. but in the two following years it was applied continuously throughout the year ; and the following were the total amount of sewage used, and of green grass obtained per acre in the course of the three years.

TOTAL QUANTITIES PER ACRE IN THREE YEARS (1861, 1862, 1863).

Sewage used per Acre.			Green Grass obtained per Acre.			
		Tons.	Tons.	Cwt.	Qrs.	lbs.
5 Acre Field.	Plot 1.	None.	22	8	0	0
	„ 2.	8,064	65	0	0	9
	„ 3.	16,417	96	9	3	0
	„ 4.	24,140	102	7	0	7
10 acre Field.	Plot 1.	None.	33	9	1	3
	„ 2.	7,388	68	13	1	2
	„ 3.	14,803	85	9	2	10
	„ 4.	22,229	93	5	2	25

So that the amounts of green grass obtained per acre per annum on the two fields were as follows :—

PRODUCE PER ACRE PER ANNUM AS GREEN GRASS.

	Plot 1. Without Sewage.				Plot 2. 3,000 tons of Sewage per annum.			
	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.
Five acre field . .	7	9	1	9	21	13	1	12
Ten acre field . .	11	3	0	10	22	17	3	1
Average	9	6	0	24	22	5	2	7

	Plot 3. 6,000 tons of Sewage per annum.				Plot 4. 9,000 tons of Sewage per annum.			
	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.
Five acre field . .	32	3	1	0	34	2	1	12
Ten acre field . .	28	9	3	13	31	1	3	18
Average	30	6	2	6	32	12	0	15

Taking the average, therefore, over the three years in the two fields, it appears that the produce of meadow grass in the plots without sewage was about 9¼ tons per acre per annum, which is equal to about three tons of hay; and with 3,000, 6,000, and 9,000 tons of sewage per acre per annum, the amounts were respectively about 22¼, 30¼, and 32½ tons of green grass, equal respectively (reckoned according to the percentage of dry substance in each) to about 5, 5¾, and 6½ tons of hay.

"The average increase obtained for each 1,000 tons of sewage was, when 3,000 tons per acre per annum were applied, about 5 tons of green grass; when 6,000 tons were applied, 4 tons 2½ cwt.; and when 9,000 tons were applied, 3 tons 3¼ cwts. of green grass."

Experiments on rye-grass were made in one season only, and comparatively small quantities of sewage were put on, but the results were much about the same, as regards the increase of produce for a given amount of sewage, as with meadow grass.

The composition of the sewaged and the unsewaged grass was carefully determined during each of the years, and it was found that "the sewaged meadow grass as cut and given to the animals, contained a less proportion of dry or solid substance than the unsewaged; and the grass cut during the later portions of the season (both sewaged and unsewaged) contained less solid matter than that cut during the more genial periods of growth. Italian rye-grass in the condition as cut, was also found to be more succulent, and to contain less solid matter when grown with sewage than without it."

"The proportion of nitrogenous substance (and also of impure waxy or fatty matter) was much greater in the solid matter of the sewaged, than in that of the unsewaged grass. The proportion of nitrogenous substance was also much higher in the solid matter of the grass grown towards the end than earlier in the season. The proportion of indigestible woody fibre was much about the same in the dry substance of the unsewaged and of the sewaged

grass. It progressively diminished as the season advanced, and was generally lower in the dry substance of the Italian rye-grass than in that of the meadow grass."

The results are shown in the following table :—

PER CENTAGE OF DRY SUBSTANCE IN THE UNSEWAGED AND THE SEWAGED GRASS.

	Plot 1. No Sewage.	Plot 2. 3,000 tons of Sewage per Acre.	Plot 3. 6,000 tons of Sewage per Acre.	Plot 4. 9,000 tons of Sewage per Acre.
Meadow grass 5 acre field	28·8	19·3	15·4	16·0
„ „ 10 „	25·3	16·7	15·5	15·8
Average	27·0	18·0	15·4	15·9
Italian Rye-grass . . .	28·3	18·1	18·6	—

MEAN COMPOSITION (PER CENT) OF THE DRY SUBSTANCE.

Nitrogenous substance (N + 6·3)	11·16	17·58	18·37	19·66
Fatty matter (ether extract)	3·41	4·13	3·95	4·04
Woody fibre	29·08	28·21	28·32	28·13
Other non-nitrogenous matters	46·73	39·09	38·08	36·91
Mineral matter (ash) . .	9·62	10·99	11·28	11·26
	100·00	100·00	100·00	100·00

The most remarkable fact is, that the proportion of nitrogenous constituents rises with the quantity of sewage used ; but this affords no indication of the nutritive power

of the grass, except that the milk yielding qualities were not in proportion to these matters—weight for weight, indeed, the earlier crops of the season, which contained the least nitrogenous matter were by far the most nutritious, and so, also, was the unsewaged grass which yielded the smallest proportions of these substances. "At one time," says Dr. Voelcker, "it was generally believed that the amount of nitrogenous matter was the measure of the nutritive quality of the produce, and Professor Way, with other chemists, having found in the grass and hay of irrigated meadows more nitrogenous matter than in ordinary produce, arrived at the conclusion that it was really more nutritious. But, now the tide has set in a different and more reasonable direction—a direction that is borne out by practical experience. Now, an excessive quantity of nitrogenous produce is regarded rather as an indication of unripeness, of which one defect is a deficiency of sugar." It would seem, indeed, that the nutritive power of such food is very much dependant on the proper maturation and elaboration of the tissues, whereby the digestibility and assimilability of the constituents are ensured.

For the purpose of testing the fattening powers of the sewaged and unsewaged grass, experiments were made on ten Hereford oxen, which were tied up in a shed and fed upon the green grass—two being supplied with unsewaged grass, and eight with the sewaged grass of the five acre field cut indiscriminately from the three plots, irrigated respectively with 3,000, 6,000, and 9,000 tons of sewage per acre per annum. In the year 1861, the animals had grass alone for the first sixteen out of the twenty weeks of the whole experiment, and they had oil-cake in addition (four pounds per head per day), during the remaining four weeks. The object was, to try grass alone in the first season, and the result was very unfavourable, so much so, that the commissioners said, in reporting of it, that "it is quite obvious from the table given that grass of the description in question, is not adapted for the fattening of oxen without the addition of other food. Indeed, one of

the animals on the sewaged grass weighed fifty-two pounds less at the conclusion of the experiment, than at the commencement of it ; and the maximum increase of any one of the oxen was 103 lbs. in the sixteen weeks, or at the rate of rather less than $6\frac{1}{2}$ lbs. per week. Taking the average of the two and the eight oxen respectively, those upon unsewaged grass gave scarcely $2\frac{1}{2}$ lbs., and those upon sewaged grass scarcely $2\frac{3}{4}$ lbs. increase per 1,000 lbs. live-weight per week ; whereas, feeding on good fattening food, such oxen should give 9 to 10 lbs. increase per 1,000 lbs. live-weight per week. In fact, these very animals did increase at this, and even a higher rate, during the subsequent four weeks, when they had, in addition to the grass, 4 lbs. of oil-cake per head per day." Having these facts before them, the commissioners, in 1862, gave oil-cake in addition to the grass from the commencement of the experiment (using ten oxen, as before), and the quantity of oil-cake amounted over the whole period of twenty-three weeks, to $3\frac{1}{2}$ lbs. per head per day. The results of all these experiments are shown in the following table :—

Results of Experiments in the Feeding of Oxen on Green Grass alone, and with Oil-cake in addition.

	1861.		1862.			
	Unsewaged Grass.	Sewaged Grass.	Unsewaged Grass.	Oil-cake.	Sewaged Grass.	Oil-cake.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Consumed per head per day . . .	88·9	105·2	105·4	3·5	126·1	3·5
Dry substance in .	23·7	21·3	23·6	3·1	20·9	3·1
Consumed to produce 100 lbs. increase of live weight . .	23,669	24,735	6,213	210	6,883	195
Dry substance in .	6,246	5,000	1,389	186	1,141	172

So that in both years a greater weight of the fresh

sewaged grass was consumed per head per day, and per 1,000 lbs. live weight per week, than of the less succulent unsewaged grass ; but the dry or solid substance contained in the latter (reckoning all that was eaten), was less than that in the former. Again, more of the sewaged grass than of the unsewaged, was required to produce 100 lbs. increase in live-weight ; though the amount of dry substance contained in the sewaged grass so required, was only about four-fifths as much as that in the unsewaged grass. But when, as in 1862, a fair allowance of oil-cake was given in addition, very much less both of fresh food and of dry solid substance of food were required to produce 100 lbs. increase in live-weight, than in 1861 with grass alone ; and considerably less of the dry or solid substance of the more succulent sewaged, than of the drier unsewaged grass was required. In the summary of these results, the commissioners say that, "when cut grass was given alone, the result was very unsatisfactory ; but when oil-cake was given in addition, the amount of increase upon a given weight of animal within a given time, and for a given amount of dry substance of food consumed was not far short of the average result obtained when oxen are fed under cover on a good mixed diet ;" and as regards profit, they say that "the money return, whether reckoned per acre, or for a given amount of sewage used, was much less with fattening oxen, than with milking cows,"—the value, in fact, per acre of the increase of live-weight, at 4d. per lb., was only £1 9s. 4d. for the unsewaged grass, and from £2 4s. 10d., to £4 19s. 2d. for the sewaged in 1861, when no oil-cake was given ; and even in 1862, when the results of better feeding were obtained, the value for the unsewaged land, exclusive of oil-cake, was but £3 9s. 10d. per acre, and of the sewaged from £11 1s. 8d., to £12 18s. 1d. per acre.

The experiments at Rugby with milch cows were rather more satisfactory, as will be seen from the following account of them. "In 1861, twelve of Mr. Campbell's cows were carefully selected and set apart to be fed on grass alone—two on unsewaged, and ten on sewaged grass, and

the experiment was so conducted over a period of sixteen weeks. It was afterwards continued for four weeks longer with an allowance of oil-cake as well as grass. In 1862, three cows were selected to receive oil-cake and unsewaged grass, and twelve oil-cake and sewaged grass, and the experiment was continued for twenty-four weeks. In 1863, twenty recently-calved cows were selected, five to be fed on unsewaged meadow grass, ten on sewaged meadow grass,

RESULTS OF EXPERIMENTS ON MILCH COWS WITH UNSEWAGED AND SEWAGED MEADOW GRASS ALONE, AND WITH OIL-CAKE.

	1861.		1862.			
			Unsewaged.		Sewaged.	
	Unsewaged. grass.	Sewaged. grass.	Grass.	Oilcake.	Grass.	Oilcake.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Consumed per head daily...	150·2	124·0	127·2	3·5	140·2	3·6
Dry substance in	35·8	22·7	25·2	3·1	23·0	3·2
Consumed per 1,000 lbs. live weight weekly...	994	846	862	23·8	941	24·1
Dry substance in	237	155	171	21·1	154	21·4
Consumed to produce a gallon of milk	62·2	62·2	55·5	1·53	67·1	1·72
Dry substance in	14·8	11·4	11·0	1·36	11·0	1·52
Milk per head daily	24·9	20·5	23·6		21·5	
Do. per 1,000 lbs. live weight weekly	164·8	140·3	160·0		144·8	
Increase in weight per 1,000 lbs live weight weekly	8·59	7.33	6 88		4·60	

RESULTS OF EXPERIMENTS ON MILCH COWS WITH UNSEWAGED AND SEWAGED MEADOW GRASS ALONE, AND WITH OIL-CAKE.

	1863.					
			Unsewaged.		Sewaged.	
	Unsewaged grass.	Sewaged grass.	Grass.	Oilcake.	Grass.	Oil-cake.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Consumed per head daily	99·1	142·9	90·5	3·9	172	3·7
Dry substance in	27·9	25·2	24·4	3·5	25·1	3·3
Consumed per 1,000 lbs. live weight weekly	650	933	563	24·1	1076	22·9
Dry substance in	183	169	151	21·5	157	20·4
Consumed to produce a gallon of milk ...	36·2	52·2	32·7	1·40	68·2	1·46
Dry substance in	10·2	9·2	8·8	1 25	10·0	1·30
Milk per head daily	28·3	28·1	28·5		26·0	
Do. per 1,000 lbs. live weight weekly ...	185	190	177·3		162·5	
Increase in weight per 1,000 lbs. live weight weekly	4·37	6·70	1·82		2·02	

and five on Italian rye-grass. The design was to give each lot grass alone for the first twelve weeks, and afterwards a certain amount of oil-cake in addition." The results of these experiments are shown in the preceding tables.

"Reviewing the results of the experiments in which sewaged was tried against unsewaged meadow grass, it is observable that, excepting in the first season (1861), the cows required more, both per head per day, and per 1,000 pounds live weight per week, of the fresh or green sewaged than of the unsewaged grass; yet the yield of milk, both per head and per 1,000 pounds live weight, was, without exception, the greater with the unsewaged grass. The increase in live weight was also somewhat the greater on the unsewaged grass in 1861 and 1862, but the contrary was the case in 1863."

"Reckoned in the fresh or green state iu which it was cut and carted, there was, in fact, in every case but one (and then the quantities were equal), considerably less of the unsewaged than of the sewaged grass required to be consumed for the production of one gallon of milk. It should be remarked, however, that the unsewaged grass was generally cut in a much riper and less succulent condition, and therefore contained a considerably higher percentage of dry or solid substance than the sewaged. It may also be here mentioned that in 1863 the cows having professedly unsewaged meadow grass, in default of a sufficient supply of it, had necessarily for a considerable part of each of the periods of twelve weeks, unsewaged rye-grass."

"Weight for weight, in the fresh or green state in which the grass was cut, weighed, and given to the cows, the unsewaged grass has, therefore, proved to be far more productive than the sewaged. But when the comparison is made, not between the amounts of grass reckoned in the fresh state, but between the amouuts of dry or solid matter which the different descriptions of grass supplied, the result is, that in only one instance was there more, and in the others there was either an equal amount or even less of dry or solid substance of sewaged than of unsewaged grass required for the production of a given amount of milk."

The general result, therefore, in regard to these points was that in both milk and increase, but especially in milk, a given weight of animal was more productive when fed on unsewaged than on sewaged grass, and that a given weight

of fresh unsewaged grass was more productive than an equal weight of fresh sewaged grass; but that a given weight of dry or solid substance supplied in sewaged grass was more productive than an equal weight supplied in unsewaged.

As regards Italian rye-grass the experiments were not conclusive, as the sewaged and unsewaged grass were given indiscriminately to the cows. It seems, however, that when grass alone was made use of, the animals consumed 159·3 lbs. per head per day. These contained 31·7 lbs. of dry solid matter, and yielded 31·4 lbs. of milk—so that 52·3 lbs. of grass, containing 10·4 lbs. of dry solid matter were required for a gallon of milk. When the rye-grass was supplemented with 3·3 lbs. of oil-cake daily, the average daily consumption was only 121·3 lbs., and the yield of milk was 28·1 lbs. per diem. On this head the Commissioners say that, "the experiments do not afford the means of strictly comparing the productive qualities of rye-grass with those of meadow grass, or of sewaged with those of unsewaged rye-grass," although the "indication is that somewhat more of the dry substance of the sewaged rye-grass than of the sewaged meadow-grass was required to produce a given result, though the difference is less during the later than the earlier period of the season. It is probable, indeed, that sewaged Italian rye-grass deteriorates less towards the end of the season than the sewaged meadow grass;" for it was noticeable that the milk-producing power of meadow grass was very different in different seasons, and at different periods of the same season. It was, in fact, very inferior in the wet and cold season of 1862, and towards the close of every season as compared with the beginning. But on an average of the three years about six parts of green grass yielded one part of milk, and as the production of grass was greater on the sewaged than on the unsewaged land, the total yield of milk per acre was much greater in the former case than in the latter.

"So far as the results of the experiments afford a means of judging, it is estimated that with an application of about 5,000 tons of sewage per acre per annum to meadow land,

an average gross produce of not less than 1,000 gallons of milk per acre per annum may be expected ;" and this at 8d. per gallon would give a return of from £30 to £35 an acre.

The quality of the milk in the two cases was carefully tested, and it was not found to differ to any great extent, although it was slightly less rich in the case of the milk

THE MEAN COMPOSITION OF THE MILK PRODUCED FROM UNSEWAGED AND SEWAGED GRASS.

Constituents of Milk.	Season 1861. Grass alone.		Season 1861. Grass and Oil-cake.		Season 1862. Grass and Oil-cake.	
	Unsewaged	Sewaged.	Unsewaged	Sewaged.	Unsewaged	Sewaged.
Casein	3·246	3·241	3·352	3·423	3·513	3·467
Butter	3·604	3·430	3·657	3·707	3·834	3·559
Sugar of milk, &c. ...	4·405	4·218	4·561	4·689	4·502	4·440
Mineral matter	0·753	0·776	0·740	0·771	0·753	0·771
Total solid matter ...	12·008	11·665	12·310	12·590	12·602	12·237
Water	87·992	88·335	87·690	87·410	87·398	87·763
Total	100·000	100·000	100·000	100·000	100·000	100·000

from the sewaged grass than in that from the unsewaged. This will be apparent from the preceding table, which represents the average composition of forty samples of milk taken during the years 1861 and 1862.

But although the chemical composition of the milk does not seem to be very different in the two cases, yet experience has shown that the milk from sewaged grass is more apt to turn or become sour than that from unsewaged, and this in one notable case was a subject of litigation in a court of law, on account of the injury done to the trade of a milk company by the frequent and rapid decomposition of milk supplied from a sewage farm. It is also worthy of note that nowhere, to our knowledge, has the keeping of cows upon a sewage farm been a profitable success. It was abandoned by Mr. Marriage, at Croydon, after a very persevering trial, and it was in like manner abandoned at Rugby by Mr. Campbell, who thus spoke of it in a letter to the *Times*, on the 18th of August, of 1869. Twelve Ayrshire cows which calved about the same time (in May, 1869), were fed on Italian rye-grass, grown on sewaged land, and at the end of twelve weeks he found that the quantity of milk averaged 9½ quarts per diem for each cow, and each cow consumed 1½ cwt. of Italian rye-grass, exclusive of other fodder. If they had been milked for nine months, the average yield of milk would have been only from 5 to 6 quarts each cow. Now the cost of the grass was 10s. per cwt., or 9d. per cow per day, and the dairy expenses were 6½d. per cow per day, making in all, 1s. 3½d. per cow; but the milk at 8d. per gallon was only worth 1s. 7d., and when the cost of sending it to market is considered, and the wear and tear of cans, he very properly asked—where is the profit? Again, in the recent report by Mr. Morgan of the last year's operations at the Lodge Farm, Barking, where the sewage costs nothing, and where it is not taken continuously, but is drawn from the main Northern outfall in such quantities, and at such times as is thought best for the land and the crops, the balance sheet is not encouraging; for although

the farm is not intended as an example of how sewage can be purified, but how it can be profitably utilised, and is worked entirely for this purpose, yet the returns on the 162 acres have been only £485 above the outgoings—and these do not include any account of remuneration to Mr. Morgan, or of the value of the sewage employed, or of the interest of capital invested. "If," says the *Standard*, in its comments on this subject, "a farmer could obtain all his manure without paying for it, there can be no doubt that his balance-sheet would be greatly improved. But if we debit the Lodge Farm with the sewage used upon it (622,324 tons on 162 acres, or 3,808 tons per acre per annum), even though we charge as little as a half-penny per ton, the profit is reduced to a very shadowy amount. At a penny a ton there is a loss of £1,268, while at two-pence per ton makes the loss equal to £3,860." Even reckoning the increase in the value of stock (£840 on £4,608 of the previous year) the profits are far from hopeful. In fact, the main features of Mr. Morgan's reports are excessively large crops and excessively low prices. He gives, indeed, a very doleful account of the market value of the farm produce. Cabbages, for instance, were sold at from 3d. to 4d. a dozen as a maximum price, the minimum being but 6d. for five dozen. Scarlet runners fetched only 3d., 6d., and 1s. a sieve in the early part of the season, and from 2s. to 2s. 6d. in the latter, and potatoes, although largely in demand, were actually sold at from £2 to £4 10s. a ton. All this had but one signification, for if general prices were ruling high as ever, the quality of the farm produce must have been remarkably inferior. As a matter of fact, indeed, there is no instance, except at Edinburgh, where a sewage farm is either commercially profitable or agriculturally successful, and there the circumstances are so unusual as to remove it altogether from the category of well-conducted farms; for the sewage is so imperfectly defæcated as to be a public nuisance.

NOISOME AND DANGEROUS EFFECTS OE SEWAGE IRRIGATION.

There are three classes of effects which render sewage irrigation more or less dangerous to the public. In the first place the emanations are offensive, and are productive of pythogenic diseases. In the second place the percolation of sewage into subsoil water, and thence into springs and wells, is not unlikely to be a source of danger; and in the third place the distribution of undefæcated sewage charged with the ova of intestinal and other entozoa is certain to produce disease in man and animals.

As regards the first point—namely, the offensive and morbific character of sewage emanations, especially in those cases where the undefæcated sewage is distributed in large quantities upon the land, there is abundant evidence. At the Craigintinny meadows, near Edinburgh, the stink is hardly endurable. To use the words of Dr. Ligertwood, who was stationed at the neighbouring cavalry barracks in 1868, "Those fields are certainly a source of nuisance to those living in barracks, from the offensive emanations given off from the open ditches conveying the sewage, and also from injudicious flushing of the fields, for the stench in the barracks is sometimes sickening." At Norwood and at Beddington the Croydon sewage farms are the subjects of constant complaint, and the neighbouring houses and property are greatly damaged in value on account of it. Mr. Creasy, the surgeon of the Orphan Asylum at Beddington, said in his evidence before a recent Parliamentary Committee, that he had known the district ever since it was a

sewage farm, and typhoid fever had been in every cottage on the estate ; every disease, in fact, assumes a particular type, accompanied by what is called "a sewage tongue." At Aldershot, Banbury, and other places which have been described, the stink of the irrigated ground is a matter of serious complaint ; but in most cases these complaints are ignored, or are met with positive denial. "Some people," says the Earl of Essex, "have grumbled at the smell, but I think they are getting tired of doing so, as I take no notice of it." That there are good grounds, however, for such complaints is evident from the remarks of those who have paid attention to the subject. Messrs. Galton, Simpson, and Blackwell, the referees appointed by the Government in 1856 to consider the question of the main drainage of the metropolis, say in their report that it is a question whether irrigation on a large scale might not occasion danger to the health of the inhabitants of such districts by the pollution of the air of the district, as well as the wells and springs ; and Liebig, in his letter to the Lord Mayor of London in January, 1865, said that the fear of producing fever by sewage emanations was not altogether groundless, especially where land was flooded with sewage and converted into a bog. Dr. Copland, in his remarks on the paper of Mr. Fothergill Cook on the "Treatment of Sewage with Lime," stated that in his opinion the effects of sewer gases were never so bad as when sewage was spread out upon the land, and he recommended some process of deodorisation or defæcation before the sewage was thus used. The Select Committee on the Sewage of Towns admit, while advocating the employment of sewage upon the land, that if the power of the soil be overtaxed, and large dressings be applied, there will be injury to wells and to running streams, and they quote Dr. Angus Smith, Mr. Alderman Mechi, Mr. John Chalmers Morton, and Mr. Francis Wyley in proof of it ; indeed the instances which have already presented themselves of the malarious effects of sewer gases are sufficient to create alarm, and to show that under some circumstances the proximity of a sewage farm is not alto-

gether devoid of danger. Dr. T. S. Clouston, the medical superintendant of the Cumberland and Westmoreland Asylum, has given an account in the *Medical Times and Gazette* (June 1865) of an outbreak of dysentery among the patients of the asylum, which he says was caused by the effluvia from a field irrigated with sewage. The asylum contained two hundred patients, and before the distribution of the sewage upon the land, the mortality and sickness were greatly below the average of such institutions; but soon after the sewage had been thus used, severe dysentery appeared among the residents of the asylum. Thirty-one persons were attacked, and of these twenty died ; besides which there was much diarrhœa of an ordinary kind. The irrigated field was about three hundred yards from the female ward, in which the greatest number of cases occurred, and it was about three hundred and fifty yards from the corresponding male ward. Both of these wards are upon the ground floor, and Dr. Clouston is of opinion that the effluvium is most concentrated near to the ground. He observed also that the effects were most marked when there was little or no wind and a high barometric pressure. Most of the cases occurred in June, July, and August, when vegetation was most active, and none of them in the winter time. It often happened that there was no marked odour of sewage, notwithstanding that it caused disease; and he was for some time very disinclined to refer the outbreak to the irrigated field, but at last, suspecting the cause, he gave orders for the sewage to be conveyed to a distant part of the farm, and then the dysentery disappeared, and those suffering from it recovered. In the following year, thinking that the sewage might be better applied, he gave directions for a more perfect levelling of the ground, and for its being better trenched and drained ; but while this was being done, the sewage again got upon the land, and caused another outbreak of the disease. Dr. Clouston was thus convinced that the sewage emanations were the cause of the dysentery and diarrhœa, as well as the cases of typhoid fever, which occurred in the asylum. Another in-

stance of a like nature occurred at Shaftesbury in the year 1862. The town had recently been drained by a person of no practical knowledge, who carried the sewage into the ditches and ponds of the neighbouring fields. In less than a year, one-eighth of the whole population was attacked with enteric fever, and the results were so serious that Dr. Letheby was requested by the local authorities to inquire into the matter; and he reports that of three thousand five hundred persons who formed the population of the place, four hundred and forty-eight were attacked with the fever. A similar case is recorded by Dr. Letheby as having occurred at Copley village, which lies at the junction of the Hebble brook and the river Calder. The village consists of about one thousand persons, and it was designed as a sort of model village by Mr. Ackroyd, who built it. Near to the village is a plot of meadow land, which was irrigated with the brook water containing the sewage of Halifax; but as typhoid fever presented itself in a serious and unmistakeable form, the process was abandoned as a measure of public safety. At the Broadmoor Criminal Lunatic Asylum, it seems to be more than probable that the continually increasing proportions of fever cases from the opening of the asylum in 1863 to the adoption of earth closets in 1869 is attributable to emanations from the land upon which the sewage of the asylum was distributed. Very recently, in the spring of the present year, an outbreak of scarlet fever at Haileybury College, near Hertford, was traced by the medical attendant, Dr. Elin, to the offensive emanations from a garden and field saturated with sewage. All the cases—twenty-three in number—occurred in the dormitories and studies nearest to the garden which received the urine and slops of the establishment, the solid excreta being collected in earth closets. It was noticed that the soil of the garden was sodden with sewage and was very offensive, and another piece of ground of about an acre in extent was therefore taken for irrigation, but this also became offensive, and then the disease presented itself. But why multiply examples of this kind, when, to use the words of Dr.

Buchanan and Mr. J. Netten Radcliffe, in their report on the systems in use in various northern towns for dealing with excrement, " the propagation of certain epidemic diseases, especially cholera, enteric fever, and diarrhœa among communities, as the result of excremental pollution of air and water, is one of the best established facts of sanitary medicine." The chief object, indeed, of sanitary practice during the last fifty years has been to prevent the infection of air with excremental effluvia ; and the most notable fact in the present century has been the recognition by Dr. Murchison of the true cause of pythogenic, enteric, or typhoid fever in the poison contained in sewage emanations. It is, however, not alone on account of the specific or special morbid action of such gases that sewage is dangerous. It is also dangerous because of the damp and sodden condition of the soil which receives it. Everywhere the experience of medical practice has demonstrated the unhealthy character of a district saturated with moisture containing organic matters. The fens of Lincolnshire, the rice fields of China, the capital sunderbunds of India, and the irrigated grounds of Italy and Southern Europe, afford abundant evidence of the malarious influences of such soils. It is a matter of grave doubt indeed whether the Campagna of Rome, which was once the favourite locality for the luxurious villas of the Roman nobility, has not derived its unhealthiness from the saturation of the soil with the filthy water of the Tiber.

Again, the researches of Dr. Buchanan and others into the effects of drainage on the prevalence of phthisis, have shown beyond all question that a dry atmosphere is less provocative of this disease than a wet one, and if this be so it is inevitable that the saturation of ground with sewage, and the raising of the subsoil water, must necessarily render the atmosphere more humid than it otherwise would be, and thus create a consumptive influence. Besides which, if the doctrines of Professor Von Pettenkofer, of Munich be correct, as they certainly seem to be, that fluctuation in the level of ground water charged with sewage is the most

active agent of fever and cholera, the consequences of irrigation may be most serious.

In addition to all this, there is the danger of polluting springs and wells to such a degree, as that the water becomes positively unwholesome, and unfit for human consumption. This is the case at Beddington, where all the wells are seriously and dangerously polluted, and it not unfrequently happens that the effluent water from irrigated ground produces illness in cattle that drink it. Even water-cresses grown in such water have caused diarrhœa in the human subject.

PARASITIC DANGERS OF SEWAGE IRRIGATION.

Entozoic diseases have always an external origin, and are generally caused by food or drink infected with the ova of parasites, or with the parasites in a larval condition,—the food or drink being in its turn infected directly or indirectly by excremental pollutions. In some cases, as with the protozoa and the nematoid worms, the ova or the mature parasite may gain access to the body of man and at once cause disease of a more or less serious character through the water which we drink, or some raw vegetable which we eat, infected with sewage. Water-cresses, celery, lettuce, endive, and other such vegetables eaten in a raw condition, may after recent sewage irrigation, convey the agents of parasitic disease. At other times, as with the cestoid forms of entozoa, helminthic disease is caused by the use of meat infected with the larvæ of parasites that have had their origin in sewage or excremental matters present in the green fodder, or other food upon which the animals have fed. A single individual infected with tape-worm will discharge from his body millions of ova, every one of which is capable of producing a measle, as it is called, in the flesh of an animal, and this in its turn a tape-worm in man. As we have elsewhere remarked, sewage contains myriads of ova of intestinal entozoa,—every segment of tape-worm discharged from the human body being crowded with them, and if distributed with sewage upon the land, will become attached to the grass and other green fodder which is grown thereon.

This is eaten by cattle, whose bodies quickly become infected with the parasite in its larval condition, and thus the measly meat becomes the agent of disease in our own bodies. At present the distribution of these ova, and their access to the bodies of herbivorous animals is entirely a matter of accident; but make it a matter of certainty, as most assuredly you will by distributing sewage upon the fodder producing land, and the consequences must be serious. Dr. Cobbold, who is our highest authority on this subject, has published an essay, warning the public of the danger of this method of distributing town sewage; and he has hinted at the probable introduction into this country of a terrible helminthic malady (*Bilharzia*) which is now common in Egypt, Africa, and the Mauritius, and which would assuredly be propagated throughout the land by this dangerous scheme of irrigation. "Have the kindness," he says, "to observe that every colonist returning from the Cape is liable to bring this parasitic treasure with him as a guest indeed, dwelling in his blood, and feeding on his life stream. In the advanced stages of the malady, the afflicted individual must frequently evacuate the eggs and their contained embryonic larvæ, which are thus conveyed into the ordinary receptacles of such voidings. There let them remain, or convey them into a cesspool, and no harm follows. If deemed preferable, you may transport them along with myriads of other human parasite eggs and larvæ into a common sewer, and thence into the sea; still entozoologically speaking, no harm follows. Here, however, let me invite you to pause, for if, without due consideration, you adopt any one of the gigantic schemes now in vogue, you will scatter these eggs far and wide; you will spread them over thousands of acres of ground; you will place the larvæ in those conditions which are known to be eminently favourable for the development of their next stage of growth, you will bring the latter in contact with land and water snails, into whose bodies they will speedily penetrate; and in short you will place them in situations where their yet higher gradations of non-sexual growth and propagation

will be arrived at. After all these changes, there is every reason to believe they will experience no greater difficulty in gaining access to our bodies here in England than obtains in the case of those same parasites attacking our fellow-creatures, whose residence is found in Egypt, in Natal, in the Mauritius, or at the Cape. In a natural history point of view, it would not be an altogether singular result if, twenty years hence, this parasitic malady should be as prevalent in this country as it is now known to be in particular sections of the African Continent. Foreseeing the possibility, not to say probability, of this contingency, am I not right," he says, "after years of long study, to raise my voice in the hope of preventing such a disaster."

Nor is it unlikely that the trichina may be distributed in the same manner, for it swarms in the intestines of those who have just become infected with it, and may be discharged into sewage and scattered upon the land, and eaten by creatures whose flesh will give it back to us again. No one, in fact, but the helminthologist, can say what particular parasite may not be distributed and propagated by this dangerous agricultural process. "May we not indeed," as Dr. Cobbold observes, "but too reasonably conjecture that the wholesale distribution of tape-worm eggs by the utilisation of sewage on a stupenduous scale, will tend to spread abroad a class of diseases, some of which are severely formidable? So convinced am I," he says, "of the truth embodied in an affirmative reply to this latter query; so certain am I that parasites are propagated in this particular way; so surely do I see unpleasant results if no steps are taken to counteract the evil, that I feel myself bound to speak out boldly, and to produce no uncertain sound in the matter which most closely concerns humanity! The whole question is in truth of vast hygienic inportance." But the Editor of the *Lancet* does not appear to entertain this opinion, for in a leader of the 4th of February last he thus expresses himself,—"Dr. Spencer Cobbold is an acknowledged master in the science of Helminthology, and as long as he speaks in that capacity

we sit humbly at his feet. But when he sets himself up for an oracle on sewage irrigation we have a fair right to examine the facts upon which his reasoning is based, and to express our opinion with an authority at least equal to his own. We are, therefore, ready to admit that Dr. Cobbold's history of tape-worm is in the main correct. Briefly, we have no reason to doubt that the ova are discharged in human excrement; that they occasionally by some means or other, get into the flesh of cows, calves, oxen, and pigs; that when they do so they appear as 'measles'; and that when such flesh is taken in an uncooked form by man, tape-worm is again produced. But whilst this may be true it by no means follows that butcher's meat is ordinarily 'measled,' or that a larger proportion of 'diseased meat' is produced on sewaged than on other farms." This is a remarkable jumble of inconsistencies; for if all tape-worms in the human subject have had their origin in measly flesh eaten by man; and measly flesh has always come from the ova of tape-worm eaten by the animal; and the ova so eaten have always been discharged with human excrement, it follows, as a matter of necessity, that wherever such excrement is most frequently found upon the pasture or green fodder eaten by cattle, there the animal must be most liable to have its flesh infected with measles. Now sewage is a liquid which is always charged to a greater or less extent with such excremental ova, and therefore the farm which receives it upon the land must be more liable to produce measly meat than the farm which has none of it; for in one case the infection of the animal s an accident, and in the other almost a certainty. Abundant evidence has been given of the greediness with which cattle will feed upon the succulent pasture of ground irrigated with sewage. Mr. Mechi states that not only have cattle no objection to sewage upon grass, but they like it so much that they follow the hose and will feed upon the grass while it is still wet with sewage. Mr. George King, a civil engineer, who has laid out several sewage farms, was asked by the Parliamentary committee on the

sewage of towns,—"at what time after the application of sewage do cattle feel inclined to feed upon the sewaged land; have they any objection to it at any time?"—to which he replied, "I think they will feed upon it immediately, even while the sewage is upon the ground; they seem to relish it at once." Mr. Tregelles, who gave evidence before the same committee, said "perhaps I need hardly state to the committee that cattle eat grass with great avidity after it has been watered with sewage manure: it is remarkable, indeed, how they will eat the land closely when they will reject spots in the field upon which their own droppings have fallen and will not touch it; but they eat the grass close to the ground where sewage has been placed." Mr. George McCann also, in answer to the question whether cattle have any objection to eating this grass after the application of sewage? said, "not the slightest; for I have seen horses, cows, and sheep eat it most eagerly before the sewage has been upon it forty-eight hours,—more so than on any other part; in fact they prefer the land watered in that way." And so strong was the testimony of farmers on this head that the select committee in their final report alluded to it, saying that "the evidence proves that cattle of all sorts appear to prefer sewaged grass to all others, and will eat it within a few hours of its being dressed with sewage." In proof of this they refer to the evidence of Dr. Angus Smith, Mr. Lawes, Mr. George King, Mr. Edwin O. Tregelles, Mr. George Henry Henderson, Mr. George McCann, and Mr. Francis Wyley. At Carlisle, where the pasture land is constantly irrigated with sewage, the sheep and cattle feed upon it continuously. At Penrith a very large stock of cattle is kept upon the land to graze down the abundant growth of grass upon the meadows which are irrigated with sewage; and at Croydon the practice used to be to irrigate the land for three or four days and nights together two or three times for each crop, and when the grass has got a sufficient head, to stop the application and turn the stock upon the land, where they remained until the grass was

closely eaten down ; they were then removed, and the land was again irrigated in a like manner. Even when the grass is cut down and carried to the sheds where the cattle are kept it is often wet with sewage. There is no difficulty, therefore, in understanding how a sewage farm is more likely to produce measly meat, than a farm not sewaged. It may well be that the butcher and the veterinary surgeon are not able to detect the measles in the meat, for unlike the measles of pork, they are very small in veal and beef, and are but sparsely distributed ; so that nothing but a thorough anatomical dissection would lead to their discovery. That they are present, however, is abundantly proved by the existence of tape-worm in man.

Another serious consequence of sewage irrigation is the spread of rot among sheep ; for experience has shown that a damp and sodden condition of the ground is peculiarly favourable for the production of the liver fluke (*Distoma hepaticum*) of sheep,—the method of development being as follows:—Ova are passed from the gall bladder of infected animals into the intestines, and so upon the land ; finding a moist situation they are soon hatched into ciliated embryos, which swim about, and become developed into cylindrical sacs of minute hydatids. These attach themselves to some small mollusc, as snails and slugs. In wet weather the infected snails crawl upon the grass and are eaten by the sheep ; and then the hydatid speedily changes its condition and becomes a fluke. Upon dry land the ova and their progeny perish, but in wet lands they retain their vitality, and often create a pestilence, that destroys whole flocks of sheep. The dangers, therefore, of sewage irrigation, even in this particular, are not undeserving of attention ; for assuredly it is a means of producing the very conditions which are required for fluke disease.

CONCLUSION.

We have now reached the end of our inquiries into the sewage question, and on reviewing the facts which have been brought to light we perceive the startling truth that however valuable the constituents of sewage may be, in theory, we have done our best to render them worthless, or nearly so, in practice; for through the meddlesomeness of our certain sanitary authorities, we have so dealt with the subject as to have not merely destroyed the agricultural value of a product, which in all time has been regarded as a rich fertiliser of the ground, but have actually brought it into such a dangerous state of decomposition as to be an almost ungovernable nuisance. In the right order of Nature there can be no doubt that the proper destination of the excretions of all animals is the soil, where they find the means of becoming elaborated for the plant, which finally returns them to us as food. But this order of things has been perverted by the creation of difficulties, which our utmost ingenuity is unable to cope with. We strive, it is true, to restore in our own fashion the waste products of animal life to the mineral and vegetable worlds for which they are destined, and to which they will return at last in spite of our meddlesome interference, but we have so altered the natural and proper condition of things, as not only to hinder, but actually to embarrass the beneficent operations of Nature. We have drowned, for example, the materials intended for the food of the plant in water that ought to flow unpolluted into the river, and then we wonder that the filthy mix-

ture defies our skill, and can neither be utilised nor purified by the action of land or water. In some cases, where large agricultural results have been achieved, as on the Craigentinny meadows at Edinburgh, all sanitary considerations are abandoned, and the sewage is allowed to flow upon the ground in such enormous quantities as to convert the locality into a stinking morass, which is a public nuisance; besides which the effluent water is so foul as not to be admissible into any decent water course, and therefore runs directly into the sea. On the other hand, when sanitary results are aimed at, as when the sewage is sprinkled upon the land by means of hose and jet, in the water-pot fashion, as was the case at Tiptree hall, at Rugby, at the Earl of Essex, and at the Voujours farm near Paris, the agricultural results were so unprofitable that, notwithstanding the ardour and strong faith of its advocates, it was at last summarily abandoned. So that whether we wish to realise commercial profit or sanitary success we are alike in a difficulty as to the right means of dealing with the subject. Attempts have been made, as we have seen in the course of our enquiries, to balance the difficulties by working in a sort of intermediate manner, between the extremes of 300 tons per acre of land per annum and 10,000 tons; but, as might have been expected from such a compromise, the results have been neither profitable nor successful; for they have combined the difficulties, and realised the disadvantages of both extremes. It is abundantly evident, indeed, from the facts before us, that sewage irrigation can never be successfully practised except under peculiar circumstances, as where the land is far removed from human habitations; where the soil is so porous as to admit of free and almost unlimited percolation; where the effluent water can be discharged at once into the sea; where the sewage can reach the land without the aid of steam power, and of long and expensive carriers; and where the produce of the land—the rank sewage grass, will find a ready sale for dairy purposes.

On the other hand, the disadvantages of sewage irrigation, as it is now practised, are so numerous, and so formidable as actually to appal us; for in the first place, it often happens that the sewer outfall is so much below the level of the land, that costly motive power and expensive conduits are required for the transport of the sewage. Secondly: the necessary quantity of land (an acre for every 25 persons) is not always to be obtained at a reasonable price, within a reasonable distance; for the land must be porous, with a moderately level surface, a proper outfall, and not liable to subsoil pollution. Thirdly: in all cases the ground must be levelled, and thoroughly drained, and otherwise prepared for the reception of the sewage. Fourthly: there is the difficulty of disposing of sewage in wet weather, when the quantity is larger than usual, and when the ground is already loaded with moisture. Fifthly: there is the pressing and imperative necessity for continually, systematically, and thoroughly defæcating the sewage, so as to produce at all times an effluent water which can be freely admitted into the neighbouring water-courses without danger of polluting them. Sixthly: there is the serious disadvantage of the non-applicability of sewage to any other crop than grass, which can only be profitably used for dairy purpose. Seventhly: the noisome character of the operations, and the filthy sodden state of the soil are undoubtedly dangerous to the public health, for a damp atmosphere reeking with sewage effluvium is known to be a prolific source of typhoid and enteric maladies. Eighthly: the subsoil water, if not properly diverted, is apt to reach the neighbouring wells, and render them unwholesome. Ninthly: there is the great probability of producing entozoic infection of both man and animals by the distribution of excremental ova upon the land and its produce. And, lastly; there is the admitted uncertainty of every practical question connected with the subject, so that it is impossible to say whether the soil should be light or porous; whether it should be drained or not;

whether the sewage should pass through the land or merely over it; whether the distribution should be by open carriers, or by loose subsoil pipes, or by means of the hose and jet; whether the dressing should be large or small; whether it should be applied in summer or winter; whether the crop should be grass, or roots, or cereals; whether the grass should be eaten green, or dried by artificial heat into hay; and whether the produce is best suited for making flesh, or producing milk: in point of fact, there is not a single question relating to the subject, which the so-called practical men are able to answer in a definitive or satisfactory manner.

All these considerations lead to the conclusion that the present method of distributing sewage upon the land is eminently unsatisfactory, for it is wasteful, it is inefficacious, it is expensive, and it is dangerous. The right way of dealing with the subject is first to defæcate the sewage by means of one or other of the best precipitating processes, and then to use the clarified water upon the land if it be thought desirable, and if not, to discharge it into a neighbouring water-course. In this manner the defæcation may be so conducted as to suit the special requirements of the case; for if the effluent water is to be employed for irrigation purposes, there is no need of such a careful and perfect disinfection of the sewage, as when the water is to be at once discharged into a neighbouring stream. By this means all desirable results may be secured; for not only may the necessary disinfection be so accomplished that the effluent water may be either used upon the land when the season permits, or discharged into an out-fall channel, but the precipitated matter may be so treated as to destroy the vitality of parasitic ova, and form the basis or compost of a merchantable manure. We thus secure the most important sanitary requirements, and the most hopeful prospect of agricultural success.

It is unfortunate that some of the Parliamentary Committees and Royal Commissions that have been created for the express purpose of dealing with this im-

portant question have approached the inquiry with a manifest bias in favour of some particular scheme, and with a preconceived opinion of the way in which the subject should be treated. They have, therefore, selected their witnesses and sifted the evidence so as to suit the particular objects in view. It is still further to be regretted that some of these commissions have been so formed as not to include a single sanitary authority of medical education and experience. What value, therefore, can be attached to the conclusions and recommendations derived from such a source? In one notable instance, where the evidence was fragrantly dealt with in an inquiry before a Committee of the House of Commons, and where, to use the words of Mr. Ker Seymour, who brought it under the notice of the House, the chairman of the Committee (Dr. Brady) "passed by one whole class of evidence, and gave prominence to the evidence of persons who agreed with him," the evidence was, by order of the House of Commons, cancelled. Next to a reprimand at the Bar of the House, this was the most severe censure that could be passed on a Member of Parliament; and it is to be deplored that the same kind of partisanship is exhibited in more recent inquiries. We pass by the cost to the public of these unsatisfactory investigations, although, perhaps it may not be out of place to quote the remarks of Lord Elcho in the House of Commons, on 7th of April of last year. "We doubt," he said, "the advantage of spending so many more thousands of pounds upon this Commission (The Royal Rivers Pollution Commission) because, looking at the knowledge already acquired, we do not think that its sittings will be worth their cost to the country. Besides upwards of £3,000 a-year for salaries, £800 are charged for travelling expenses, and £700 a-year for the laboratory; and the expenses of reporting and printing are enormous." It would be interesting to the public if Parliament were to inquire whether the laboratory and its appointments are used for private as well as public professional purposes,

and whether, if such be the case, it is in accordance with the rules of the House, or in accordance with the terms of the appointment.

Here, then, we leave the subject, and, in so doing, we put a final question—whether the present system of removing excremental matters from our houses by the agency of water has not created more waste, and greater sanitary danger, and more expensive litigation than any other system which the ingenuity of man could have devised? not forgetting that the water which is thus wastefully and irreparably fouled amounts to from 20 to 30 gallons per head of the population daily, and has been brought at great cost from the purest sources, and perhaps, filtered in the most careful manner. What other nation would have been guilty of such folly?

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